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# THE CRRES TIME HISTORY DATA BASE - ALL SENSORS

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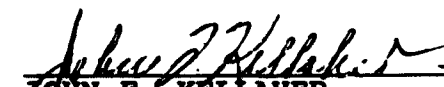
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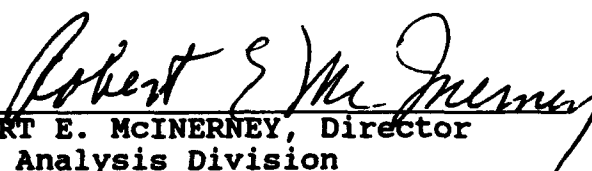
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## **1.0 INTRODUCTION**

The Combined Release and Radiation Effects Satellite (CRRES) payload included a number of instruments designed to provide data on particles, fields, and waves.

The Time History Data Base (THDB) for the CRRES mission provides the data source for short time duration event studies as well as long term efforts involving statistical analyses and modeling efforts. Prime uses of the THDB include the development of the static radiation belt model and cosmic ray model.

The purpose of this document is to define the analysis procedures, the instrument THDB file formats, and when possible, the algorithms necessary for the conversion of THDB parameters to science units.

Chapter 1 contains an overview of the overall effort, the data flow, and the generic THDB structure.

Each succeeding chapter is devoted to one instrument (or element) for which the data is to be stored in the THDB. Each of the chapters contains a brief description of the instrument, the data reduction procedures necessary for THDB generation, the parameter list which represents the information derivable from the THDB, and the THDB file structure. The brief instrument description in each of these chapters was extracted from the "CRRES/SPACERAD Experiment Descriptions" document edited by M.S. Gussenhoven, E.G. Mullen, and R.C. Sagalyn. This document, dated 24 January 1985, is an AFGL Technical Report (AFGL-TR-85-0017). The data reduction procedures and techniques resulted from discussions with a number of Principal Investigators and their analysts.

The THDB consists of structured, time ordered data sets from selected spacecraft sensors along with necessary attitude data, and ephemeris data.

### **1.1 CRRES DATA FLOW**

The down-linked telemetry data was recorded on instrumentation tape. The PL/GPD decommutation process input the data from the instrumentation tapes and produced major frame formatted files of the full telemetry stream. These files were networked through to the mass storage device. The Agency Tape software was executed to access the master frame formatted files and produce the header files, magnetic field files, ephemeris files, attitude determination coefficient files, and the agency dependent telemetry file structures. These files were produced on an orbit by orbit basis. An orbit was defined as a spacecraft revolution about the earth starting at perigee and ending at the following perigee. The telemetry files received by each individual agency contain only the telemetry parameters required by that agency. Periodically, the agency files resident on mass storage were

copied to digital tape for dissemination to the appropriate agencies. These digital tapes are referred to as Agency Tapes.

The THDB analysis techniques and software access the Agency Tape files from the mass storage device and write the THDB files back to mass storage.

File naming conventions were developed so that files for experiments and orbit numbers could be uniquely identified.

## 1.2 THDB STRUCTURE

Since the CRRES spacecraft has a number of sensors in its payload and operated on a 24 hour duty cycle, a philosophy adopted allowed for THDB creations in such a way that post-launch modifications to information such as calibration data did not impact the THDB creation procedures. Further, some instruments required periods of on-orbit data to determine instrument background levels and calibration parameters. Since some of this information was not available for a period of time, the generation of the THDB in calibrated form would have been held up, or, in some cases, required regeneration as new or updated information was received.

Generically, each THDB file contains the data for one orbit, unless otherwise specified. Each file is:

- generated in big-endian binary integer form using INTEGER\*4, INTEGER\*2, and BYTE (INTEGER\*1) construction. This technique allows direct input into routines hosted on all byte oriented systems.
- contain time tagged, uncalibrated, structured data sets. Internal record structures have been designed for logical input into data analysis routines.
- contain fixed length records throughout the file.
- consist of a header record followed by a series of data records. The header record contains file unique information such as date and THDB file ID.
- contain data quality flags.

Through the use of integer storage for the telemetry data portions of the THDB, flexibility is provided which allows individual Phillips Laboratory (PL) users to have data access from various computers (e.g. CDC, Convex, Sun, VAX, or PC). The use of INT\*4, INT\*2, or INT\*1 structures provides additional data compaction.

In general, the telemetry information is stored at the full data rate. Frame structures consist of a UT time tag and data



groupings into logical structures (e.g. for particle sensors, the logical grouping consist of the data for a full spectrum arranged from lowest to highest energy).

The THDB files are generated on an orbit by orbit and instrument by instrument basis.

Some of the information in this report has appeared in previous reports, but is included here to provide a single, complete description of the CRRES Time History Data Base.

Calibration equations and formulas for the conversion of telemetry data to science units should be considered to be preliminary. Many of the formulas were obtained from Principal Investigators during pre-launch discussions.

## **2.0 AFGL-701-2 SPACE RADIATION DOSIMETER**

### **2.1 INSTRUMENT DESCRIPTION**

The primary purpose of the Space Radiation Dosimeter is to measure the radiation dose from both electrons and protons as well as the number of nuclear star events occurring behind 4 different thicknesses of aluminum shielding. In addition, it provides some information on the integral flux of electrons and protons at energies above the thresholds defined by the shields. The experiment provides information on the relationship between the flux of high energy particles incident to the spacecraft and the actual radiation dose to which microelectronic components are exposed. This information is required for determination of the relationship between variations in the earth's radiation belts and the behavior and lifetime of microelectronic components.

The basic measurement technique is to determine the amount of energy deposition occurring in a simple solid state detector from particles with sufficient energy to penetrate an omnidirectional aluminum shield of known thickness.

The solid state device selected as the active measuring element is a p-i-n diffused junction silicon semiconductor with a guard ring.

Each device is mounted behind a hemispheric aluminum shield. The aluminum shields are chosen to provide electron energy thresholds for the four sensors of 1, 2.5, 5, and 10 MeV and for protons of 20, 35, 51, and 75 MeV.

The dose is taken to be directly proportional to the total energy deposited in the detector.

## 2.2 REDUCTION PROCEDURES

The instrument has two main telemetry modes (A and B). The telemetry designation carrying data from each of these modes is S29 which reads out 20 times per major frame. The data is located on subcom 16 subframes 0, 1, 2, 3, 4 (MOD 8). The word order for each of the 20 words must first be reversed; then within each word, the bit order must be reversed from the normal convention (bit7 is the LSB and bit 0 is the MSB). The bits must be properly ordered before beginning any decoding of information. The 20 readouts actually consist of 4 sets of 5 readouts (one set for each dome) on subframes 0-4, 8-12, 16-20 and 24-28. The sets of 5 consecutive subframes (40 bits) contain 36 information bits which identify mode, a channel (dome) identifier and the data bits of mode A or mode B. Data from this instrument is obtained in GTO, LAS, and ENG/CSM telemetry modes.

The description of the word AFGL 701-2 telemetry data is given below. This description assumes that the word and bit order for each telemetry word has been reversed from that which is received in the telemetry stream.

WORD 1	WORD 2	WORD 3	WORD 4	WORD 5	
7654 3 2 1	0765 43	2107 65 43210	765 43210	765 43210	
UUUU I M D	EEEE MM	EEEE MM SSSSS	EEE MMMMM	EEEE MMMM	MODE A
	P DOSE	E DOSE	SFLUX	PFLUX	EFLUX

WORD 1	WORD 2	WORD 3	WORD 4	WORD 5	
7654 3 2 1	07 6543	21 0765 43210	765 43210	7654 3210	
UUUU I M D	MM RRRR	MM RRRR SSSSS	EEE MMMMM	EEEE MMMM	MODE B
			SFLUX	PFLUX	EFLUX
	PROT	ELEC			
	RIPL	RIPL			
	CTR	CTR			
	BITS 4&5	BITS 4&5			
	OF PDOSE	OF EDOSE			
	MANTISSA	MANTISSA			

U = UNUSED

I = MODE ID [0=MODE A; 1=MODE B]

M = CAL ID [0=NORMAL MODE, 1= CAL MODE]

D = DOME [0=DOME 2,3 OR 4; 1=DOME1]

### PARAMETER:

PDOSE EXPONENT A:  $APE = 8 \cdot B4 + 4 \cdot B5 + 2 \cdot B6 + B7$

PDOSE MANTISSA A:  $AP = 2 \cdot B8 + B9$

B:  $BP = 2 \cdot B4 + B5$

PDOSE RIPPLE CTR B:  $BPR = 8 \cdot B6 + 4 \cdot B7 + 2 \cdot B8 + B9$

EDOSE EXPONENT: A:  $AEE = 8*B10 + 4*B11 + 2*B12 + B13$

EDOSE MANTISSA: A:  $AE = 2*B14 + B15$

B:  $BE = 2*B10 + B11$

EDOSE RIPPLE CTR B:  $BER = 8*B12 + 4*B13 + 2*B14 + B15$

STAR FLUX: A:  $AS = 16*B16 + 8*B17 + 4*B18 + 2*B19 + B20$

B:  $BS = 16*B16 + 8*B17 + 4*B18 + 2*B19 + B20$

PFLUX EXPONENT: A:  $FPE = 4*B21 + 2*B22 + B23$

B: AS ABOVE

PFLUX MANTISSA: A:  $FP = 16*B24 + 8*B25 + 4*B26 + 2*B27 + B28$

B: AS ABOVE

EFLUX EXPONENT: A:  $FEE = 8*B29 + 4*B30 + 2*B31 + B32$

B: AS ABOVE

EFLUX MANTISSA: A:  $FE = 8*B33 + 4*B34 + 2*B35 + B36$

B: AS ABOVE

The instrument was preprogrammed to operate in a pattern of one mode A data set followed by 15 mode B data sets. Although the modes are interlaced in this pattern, the data from each of the modes is required to obtain the full set of science data.

In mode A, the data bits represent accumulated proton (HILET) and electron (LOLET) dose; integral electron and proton flux; and star flux. In mode B, the mode A parameters are readout along with delta dose rates for electrons and protons. The inclusion of delta dose rates in mode B is made possible by including only the two least significant bits of the accumulated electron and proton dose values.

The THDB consists of compressed counts for all readouts. Because of the complexity in determining the delta dose values, the full data set is stored. In addition, to enhance data compression, bit order is reversed and the restructured words stored in byte form. One data base record is generated with data from 4 major frames. The data for the 4 domes is structured to begin with dome 1, and be followed by the other domes, in sequence. The UT time tag has been adjusted to coincide with the minor frame containing the dome 1 data.

The calculation of HILET and LOLET integral flux is relatively straight forward. The 8 bit compressed telemetry values must be extracted and the exponent and mantissa determined. After applying the decompression algorithm, the true counts are then converted to star flux in as relatively straight forward manner.

The value of total dose can be obtained from the mode A data and the immediately following mode B data. Mode A contains the 4 exponent bits and the 2 MSBs of the mantissa; mode B contains the 2 LSBs of the mantissa. Since the dose measurement is cumulative, the counts values 'rollover' each time the maximum allowable counts have been exceeded. The rollover rates for each of the domes and data types vary. It is essential to the

calculation of total dose that the number of rollovers be determined and maintained over the mission.

The delta dose value is computed using an algorithm developed for use with a similar sensor flown on a DMSP satellite. It should be noted that the algorithm required refinement with on-orbit data. Basically, the delta dose counts (ripple counter) data is differenced at successive readouts. Since the counts values can rollover, the determination of the number of roll-overs can be approximated by use of the integral flux. The approximated value of the number of roll-overs is then used in an expression to compute, and verify, the true number of roll-overs. Special considerations must be made for the cases where a mode B data set is bounded on either side by a mode A data set since mode A does not contain ripple counter information. In these cases, the value of the ripple counted must be approximated in the mode A data frame.

### 2.3 PARAMETER LIST

The following parameters for each of the four domes are available at 4.096 s intervals:

Accumulated HILET dose  
Accumulated LOLET dose  
Star flux  
Integral HILET flux counts  
Integral LOLET flux counts  
HILET dose rate  
LOLET dose rate

### 2.4 THDB DATA RECORD STRUCTURE

The THDB files for the AFGL 701-2 consist of a header record followed by a series of data records. The header record is in 32 bit positive integer form. There is data from four major frames in each of the data records (16.384 seconds). The order of the data for the four domes is dome 1, dome 2, dome 3, and dome 4.

HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (7012)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-30	Vacant (Zero fill)

DATA RECORDS:

# Word No. Description

- 1 UT (milliseconds)
- 2 Bit 27=Dome Dropout flag (0=no dropout, 1=dropout)  
Bit 26= Mode ID bit (I)  
Bit 25= Cal ID bit (M)  
Bit 24= Dome ID bit (D)  
Bits 23-16:In mode A; PDOSE (bbEEEEEMM) for dome 1  
In mode B; PDOSE mantissa and Proton ripple counter (bbMMRRRR) for dome 1  
Bits 15- 8:In mode A; EDOSE (bbEEEEEMM) for dome 1  
In mode B; EDOSE mantissa and Electron ripple counter (bbMMRRRR) for dome 1  
Bits 7-0:Star flux (bbbSSSSS) for dome 1
- 3 Bits 31-24:Proton Flux (EEEMMMMM) for dome 1  
Bits 23-16:Electron Flux (EEEEMMMM) for dome 1  
Bit 11 = Dome Dropout flag (0=no dropout, 1=dropout)  
Bit 10 = Mode ID bit (I)  
Bit 9 = Cal ID bit (M)  
Bit 8 = Dome ID bit (D)  
Bits 7-0: In mode A; PDOSE (bbEEEEEMM) for dome 2  
In mode B; PDOSE mantissa and Proton ripple counter (bbMMRRRR) for dome 2
- 4 Bits 31-24:In mode A; EDOSE (bbEEEEEMM) for dome 2  
In mode B; EDOSE mantissa and Electron ripple counter (bbMMRRRR) for dome 2  
Bits 23-16:Star flux (bbbSSSSS) for dome 2  
Bits 15- 8:Proton Flux (EEEMMMMM) for dome 2  
Bits 7- 0:Electron Flux (EEEEMMMM) for dome 2
- 5 Bit 27=Dome Dropout flag (0=no dropout, 1=dropout)  
Bit 26= Mode ID bit (I)  
Bit 25= Cal ID bit (M)  
Bit 24= Dome ID bit (D)  
Bits 23-16:In mode A; PDOSE (bbEEEEEMM) for dome 3  
In mode B; PDOSE mantissa and Proton ripple counter (bbMMRRRR) for dome 3  
Bits 15- 8:In mode A; EDOSE (bbEEEEEMM) for dome 3  
In mode B; EDOSE mantissa and Electron ripple counter (bbMMRRRR) for dome 3  
Bits 7-0:Star flux (bbbSSSSS) for dome 3
- 6 Bits 31-24:Proton Flux (EEEMMMMM) for dome 3  
Bits 23-16:Electron Flux (EEEEMMMM) for dome 3  
Bit 11 = Dome Dropout flag (0=no dropout, 1=dropout)  
Bit 10 = Mode ID bit (I)  
Bit 9 = Cal ID bit (M)  
Bit 8 = Dome ID bit (D)  
Bits 7-0: In mode A; PDOSE (bbEEEEEMM) for dome 4  
In mode B; PDOSE mantissa and Proton ripple counter (bbMMRRRR) for dome 4
- 7 Bits 31-24:In mode A; EDOSE (bbEEEEEMM) for dome 4  
In mode B; EDOSE mantissa and Electron ripple counter (bbMMRRRR) for dome 4  
Bits 23-16:Star flux (bbbSSSSS) for dome 4

	Bits 15- 8:Proton Flux (EEEMMMMM) for dome 4
	Bits 7- 0:Electron Flux (EEEEMMMM) for dome 4
8-14	Repeat order of words 1-7 for next major frame
15-21	Repeat order of words 1-7 for next major frame
22-28	Repeat order of words 1-7 for next major frame
29-30	Vacant

#### Notes:

1. In areas of telemetry dropout, dummy fill (1 fill) is inserted and the telemetry dropout flag set to 1.

### 3.0 AFGL-701-3 METAL OXIDE SEMICONDUCTOR (MOS) DOSIMETER

#### 3.1 INSTRUMENT DESCRIPTION

The objective of the Metal Oxide Semiconductor (MOS) Dosimeter is to measure integrated dose, D, as a function of depth in aluminum. Radiation-soft, PMOS transistors are placed beneath various thicknesses of aluminum in order to get the desired dose-depth curve. The integrated dose is determined by measuring the shift in transistor threshold voltage. The relationship between shift in threshold voltage and D is determined with a calibrated radiation source, usually Co-60 gamma rays.

In the package to be flown, four sensors (PMOS transistors) is operated at positive gate biases. By different thicknesses of aluminum above the sensors, a measure of the integrated doses due primarily to electrons and protons at different depths is obtainable. This information is a subject of substantial interest since even radiation-soft devices flown in space survive for much longer times than would be predicted from laboratory experiments and from the integrated dose predictions of the currently accepted space radiation models.

The measurement of the integrated dose is a very simple one. The parameter measured to determine dose is the shift in threshold voltage VT according to the relationship

$$\{\delta\} VT = R A D.$$

Since it is not possible to reset the threshold during flight, the total shift is measured as a function of time, and therefore provides a measure of integrated flux. In the above expression, R and A are constants to be determined in the laboratory.

#### 3.2 REDUCTION PROCEDURES

The analog values corresponding to accumulated dose sampled by the four PMOS transistors are readout on A196, A197, A198 and

A199, respectively. Each of these values is sampled once per major frame. There are two operating modes: "read" for normal data taking and "expose" for calibration. Bilevel B27 can be used to distinguish read and expose modes. In addition, there is a reference voltage monitor (A201) and a temperature monitor (A200).

The telemetry locations for the pertinent words are given below. The labeling conventions are as follows: the subcoms are numbered from 0-19; the minor frames are numbered from 0-31; and the bits within a telemetry word are numbered from 7 (MSB) to 0.

Word No.	Subcom Number	Minor Frame	Bits
A196	17	25	All
A197	17	26	All
A198	17	27	All
A199	17	28	All
A201	10	27	All
A200	10	26	All
B27	14	16	Bit 3 for expose/read (0=expose;1=read) Bit 2 for power on/off (1=power on)

Bilevel (B27) is the key to being able to determine areas where dose measurements can be made. The bilevel must be used to determine whether the instrument is in read or expose mode. Normally, the instrument is in expose mode. Changes between read and expose modes are performed by uplink command to the instrument. If the instrument is in expose mode, no dose calculations can be performed. When the mode switches to READ mode, it should remain in that mode for a minimum of 5 minutes. Note that there may some orbits when READ mode never occurs and, thus, for these orbits no dose data is available.

After converting the A196-A199 analogs to telemetry volts, they may be converted to dose.

$$\text{Dose}(i) = \{[a(i) + b(i) * V(i)] - c(i)\} / d(i).$$

where  $V(i)$  are the 4 analogs converted to telemetry voltage (telemetry VOLTS = .02 \* PCM COUNTS) and

i	a(i)	b(i)	c(i)	d(i)
1	2.941	.6667	3.555	416.
2	2.242	1.1666	3.223	414.1
3	2.390	1.0000	3.275	415.1
4	3.141	.2500	3.406	406.6 .

There may be a slight post-launch correction to this procedure which involves the use of the reference voltage and the temperature monitor.

Once any of the sensors reaches saturation, there is no additional information from that sensor since there is no reset.

The THDB has one record per major frame consisting of the analog voltages (in millivolts) for the four PMOS transistors; PCM counts for the temperature and reference voltage monitors; and the bilevels for expose/read and on/off. The file is generated for only those periods where the instrument is in READ mode.

### 3.3 PARAMETER LIST

Integrated dose for each of the four PMOS detectors is available approximately once per orbit.

### 3.4 THDB DATA RECORD STRUCTURE

The AFGL 701-3 THDB files consist of a header record followed by a series of data records. The header record is in 32 bit positive integer form. For the data records, there is one record per major frame (4.096 sec) in areas where the instrument is in READ mode.

#### HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (7013)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)

#### DATA RECORDS:

##### Word No.

1	UT (milliseconds)
2-5	Telemetry volts (millivolts) for the 4 PMOS transistor (Telemetry words A196,A197,A198, A199)
6	Four bytes. The most significant byte contains telemetry counts for temperature (A200); next byte contains telemetry counts for reference voltage monitor (A201); next byte contains expose/read discrete in its LSB; the least significant byte contains the power on/off discrete in the LSB.

### 4.0 AFGL-701-4 HIGH ENERGY ELECTRON FLUXMETER (HEEF)



#### 4.1 INSTRUMENT DESCRIPTION

The High Energy Electron Fluxmeter (HEEF) is a solid state spectrometer telescope designed to measure the differential energy spectrum of electrons in the energy range from 1 to 10 MeV. Electrons in this energy range are the source of a significant portion of the total radiation dose received by microelectronic components in space systems operating in the Earth's radiation belts. As such, a determination of the average value and dynamic behavior of these electrons is critical to the mission of the Combined Release/Radiation Effects Satellite.

The High Energy Electron Fluxmeter is a telescope-type instrument in which a single BGO scintillating crystal is used to detect and measure the electrons with energies between 1 and 10 MeV. In order to overcome the background problems encountered in the past by similar instruments, an electron, to be counted, must produce a triple coincidence of pulses, one in the BGO crystal and one in each of two solid state detectors; additionally, it must have a single anticoincidence with a plastic scintillator surrounding the BGO crystal.

The BGO pulses are analyzed into ten energy bins.

#### 4.2 REDUCTION PROCEDURES

The prime data from the HEEF is carried on telemetry designation S30 which appears 9 times per minor frame. In GTO and CSM telemetry modes, the minor frame word locations are 20, 52, 84, 116, 148, 180, 212, 244, and 246; in LASSII mode the locations are 35, 38, 99, 102, 163, 166, 227, 230, and 233. For each of these minor frame words, the bit order is reversed from the normal convention (e.g. if the readout is 11 bits, reverse the order of the 11 bits; if the readout is 8 bits, reverse the order of the 8 bits); the MSB represents the least significant data bit and the LSB represents the most significant data bit. As the initial step in the processing, the bit order is reversed to produce data in the normal convention. A full set of instrument readouts occurs every four minor frames and thus consists of 288 bits. Readouts from the 10 differential flux channels, the eleven singles channels, the integral flux channel, the 3 discretes and the HV monitor are strung together in the sequence of bits. Not all readouts are represented by the same number of bits, e.g. the 6 high energy differential flux channels are 10 bit readouts while the 4 low energy channels are 12 bit readouts.

The word order, data length, and exponent/mantissa information is as follows:

Channel	Bits	Exp bits	Mantissa bits
SF2	11	3	8
S1F	11	3	8

W1F	12	4	8
W2F	12	4	8
S2B	11	3	8
S1B	11	3	8
W1B	13	3	10
W2B	13	3	10
L10S	13	3	10
L10C	13	3	10
L9	10	0	10
L8	10	0	10
L7	10	0	10
L6	10	0	10
L5	10	0	10
L4	10	0	10
L3	12	0	12
L2	12	0	12
L1	12	0	12
LL	12	0	12
BGO	13	3	10
LS	12	4	8
MB1	1	0	1
MB2	1	0	1
MB3	1	0	1
HVM	8	0	8

The 288 bit readout is sequentially stripped of the appropriate number of bits to extract the individual words. The THDB has the compressed counts from the 12 integral flux channels, the 10 differential flux channels and a packed word consisting of three discretes and the PCM counts for the HV monitor. The differential and integral flux data as well as the singles channels is stored in 16 bit words to allow for data compression. One THDB record is generated for every 4 minor telemetry frames.

The decompression algorithm to be used for the integral flux and singles channels is as follows:

$$\text{TRUE COUNTS} = M * 2^E$$

where M is the mantissa and E is the exponent.

Conversion of decompressed counts to both integral flux and differential flux is accomplished by means of one constant per channel.

#### 4.3 PARAMETER LIST

Differential flux for 10 electron channels (1-10MeV), integral flux, and the data for 11 singles channels are available at 0.512 second intervals.

#### 4.4 THDB DATA RECORD STRUCTURE

The THDB file consists of a 16 word (32 bit words) header record followed by a series of data records.

There is one data record per 0.512 seconds (4 telemetry frames). The compressed counts for the differential and integral channels as well as the singles channels are stored in 16 bit words.

#### HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (value is 7014)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-16	Vacant (Zero fill)

#### DATA RECORDS:

Word No.	Description
1	UT (milliseconds)
2-6	Compressed counts for the 10 pt differential electron spectrum. The word order is L9, L8,...,L1, LL.
7-12	Compressed counts for the singles channels and the integral channel. The word order is S2F, S1F, W1F, W2F, S2B, S1B, W1B, W2B, L10S, L10C, BGO, and LS.
13	Bilevels MB1, MB2, MB3 and 8 bit HVM counts stored in the 11 LSBS of this word.
14	Dropout flag.
15-16	Vacant

#### Note:

1. Dummy fill (1's fill) is used for dropout within a spectrum.
2. The dropout flag has the value '1' if dropout occurred anywhere within the .512 second period.

### 5.0 AFGL-701-5A MEDIUM ENERGY ELECTRON SPECTROMETER (MEES)

#### 5.1 INSTRUMENT DESCRIPTION

The Medium Energy Electron Spectrometer measures electrons with energies of order of magnitude 100 - 1000 keV. This sensor uses a uniform magnetic field of 850 gauss to momentum analyze electrons incident through an aperture. The electrons experience a  $V \times B$  force which constrains them to circular, or helical, paths within the instrument. An array of lithium-drifted silicon detectors at the 180 degree primary focus is used to detect them. The 180 degree focusing principle, which relies on the fact that

chords subtending angles near 180 degrees do not differ much in length from a diameter of a circle, does not affect the motion parallel to the magnetic field and hence the focusing is effective in only one plane. Momentum analysis is achieved by virtue of the fact that the radius of the circle is proportional to the momentum of the charged particle. Electrons with similar momenta, or energies, which enter the aperture at various angles are focused into a vertical bar with the approximate width of the entrance aperture. At this focal plane, there are 18 detectors, one of which is covered and is used to measure penetrating particles such as cosmic rays. The other 17 detectors are used to separate the energy range of the instrument into 17 differential energy channels.

Data for this sensor is acquired only when the spacecraft is operating in GTO telemetry mode.

## **5.2 REDUCTION PROCEDURES**

The telemetry data for the 701-5A instrument is readout on the Aerospace data processing unit designated DPU57. The full DPU57 is readout on telemetry designation S33. The 12 bit compressed counts readouts corresponding to the 17 differential electron flux channels and the background value are readout every 0.512 seconds. Nine of the eighteen values are readout on every other minor frame. A nine bit sync word located in minor frame word 5 and the most significant bit of minor frame word 8 is to be used in determining the initial frame from which to extract data. This sync word appears in the same word location once every 8 minor frames. If the value of the sync word in the telemetry does not match the expected structure, the data is suspect at best and a flag is set in the data base to indicate that a non-matching sync pattern was found. In addition, should data dropout occur anywhere within a spectrum, the missing points are 1's filled and a telemetry dropout flag set to 1 to indicate that telemetry dropout occurred within the frame. The first 9 values (MEA0-MEA8) occur on the same minor frame as the sync word; the remaining points of the spectrum (MEA9-MEA17) are two minor frames later. Minor frame words 69, 72, 73, 100, 101, 104, 133, 136, 137, 164, 165, 168, 197, and 200 contain the compressed counts values for each pair of minor frames containing the full spectrum. For the spectra data, each 12 bit compressed counts value is placed in a 16 bit word and stored in the THDB.

The data format for DPU57 along with the word designations follows. This DPU contains the data for the AFGL 701-5A, AFGL 701-5B, AFGL 701-7A, and AFGL 701-7B sensors.

DPU57 is readout on telemetry designation S33 which is located on 18 minor frame words. The minor frame word numbers are: 69, 72, 73, 100, 101, 104, 133, 136, 137, 164, 165, 168, 197, 200, 201, 228, 229, and 232. Blocks of DPU57 data are readout over 8 minor frames.

NAME	BITS	TYPE DESCRIPTION
C	1	S MEB Sensor calibrate status. 0:off, 1:on.
CA0-CA3	8	R Alcohol radiator Cerenkov rate scalars(RP). 1 second integration time.
COMMAND VERIFICATION	16	S Echo of 16-bit serial digital command received by DPU.
CS0-CS3	8	R Fused silica radiator Cerenkov rate scalars (RP). 1 second integration time.
DSE	4	S MEB electron detector selected for PHA (1-10).
DSP	2	S MEB proton detector selected for PHA(1-4).
DPU HSK	8	A Analog data subcom from the DPU.
E0-E13	8	MEB electron detector PHA RAM scalar counting rates.
FORMAT/2	7	S Defines position in a major frame.(0-126 in steps of 2).
IDE0-IDE9	8	R MEB integral counting rates for 10 electron det.
IDP0-IDP3	8	R MEB integral counting rates for 4 proton det.
K	1	S RAM check status flag; 0: RAM ck passed,1:ckfailed
M	1	Photometer mode indicator (1=photometer)
MEA0-MEA17	12	R MEA rate scalars. 0.5 second int. time.
MEB-PROG	5	S MEB detector selection pattern program.
N	1	S Format mode; 0:Normal, 1:Special release mode
P0-P11	8	R MEB proton detector PHA RAM rate scalar counting rates.
PBKGND	8	R MEB proton detector background counting rate.
PCOINC	8	R MEB proton detector coincidence counting rate.
PS U,L (0,1)	8	R Upper and lower Proton Switch rate scalars. 2 thresholds, 4 second integration time.
RE0-RE3	8	R Electron scatter detector rate scalars (RP). 2 second integration time.
RM0-RM3	8	R M-detector rate scalars (RP). 2 sec int. time.
S	1	S Sun pulse bit; 0:No sun pulse, 1:Sun pulse recd.
SYNC WORD	9	S FORMAT/2 sync word. Value=110001010.
T	1	S Defines TM contents; 0:sensor data;1:Dum p/fixed.
W	1	S W=1 means RAM reloaded from ROM due to detected fault.

**Data Types:**

R: 8 or 12 bit compressed counting rates, 4 bit exponent.

S: Status bits, bytes, words.

A: Analog bytes convertible to engineering units.

The pattern below continues for every 1.024 seconds. DPU57 also has a Photometer mode, Memory Dump Mode, and Fixed Telemetry Mode. Data from the Memory Dump and Fixed Telemetry modes is not included in the THDB.

**CRRES TELEMETRY FORMAT -DPU57  
NORMAL MODE - 01OCT86 (REV E)**

		WORD 5 69,133,197	WORD8 72,136,200	WORD9 73,137,201	WORD36 100,164,228	WORD37 101,165,229	WORD40 104,168,232
FMT	FRM	-----		-----	-----	-----	-----
0	0	SYNC=110001010	FORMAT/2 CTR	DPU-HSK	CA 0	CS 0	RE(0,2)
	1	MEA 0	MEA 1	MEA 2	MEA 3		
	2	MEA 4	MEA 5	MEA 6	MEA 7		
	3	MEA 8	DSE	IDE 0	IDE 6	E 0	E 1
	4	E 2	E 3	E 4	E 5	E 6	E 7
	5	E 8	E 9	E 10	E 11	E 12	E 13
	6	IDE 1	IDE 2	IDE 3	IDE 4	IDE 5	IDE 7
	7	IDE 8	IDE 9	IDP 0	IDP 1	IDP 2	IDP 3
-----							
1	0	PCOINC	PBKGD	K V T - C S DSP	CA 1	CS 1	RM(0,2)
	1	MEA 9	MEA 10	MEA 11	MEA 12		
	2	MEA 13	MEA 14	MEA 15	MEA 16		
	3	MEA 17	DSE	IDE 0	IDE 6	E 0	E 1
	4	E 2	E 3	E 4	E 5	E 6	E 7
	5	E 8	E 9	E 10	E 11	E 12	E 13
	6	P 0	P 1	P 2	P 3	P 4	P 5
	7	P 6	P 7	P 8	P 9	P 10	P 11
-----							
2	0	COMMAND VERIFY		PS U,L(1,2)	CA 2	CS 2	RE(1,3)
	1	MEA 0	MEA 1	MEA 2	MEA 3		
	2	MEA 4	MEA 5	MEA 6	MEA 7		
	3	MEA 8	DSE	IDE 0	IDE 6	E 0	E 1
	4	E 2	E 3	E 4	E 5	E 6	E 7
	5	E 8	E 9	E 10	E 11	E 12	E 13
	6	IDE 1	IDE 2	IDE 3	IDE 4	IDE 5	IDE 7
	7	IDE 8	IDE 9	IDP 0	IDP 1	IDP 2	IDE 3
-----							
3	0	PCOINC	PBKGD	M MEBPROG S DSP	CA 3	CS 3	RM(1,3)
	1	MEA 9	MEA 10	MEA 11	MEA 12		
	2	MEA 13	MEA 14	MEA 15	MEA 16		
	3	MEA 17	DSE	IDE 0	IDE 6	E 0	E 1
	4	E 2	E 3	E 4	E 5	E 6	E 7
	5	E 8	E 9	E 10	E 11	E 12	E 13
	6	P 0	P 1	P 2	P 3	P 3	P 5
	7	P 6	P 7	P 8	P 9	P 10	P 11
-----							

The data is 'sample and hold' with a .512 second time difference between the time of data sampling and the time that the first of the points is readout to telemetry. All spectra points are sampled over the same time period.

The decompression algorithm to convert to true counts requires the extraction of the 3 MSBs and the 9 LSBs of the 12 bit word. The 3 MSBs represent the exponent (e) and the 9 LSBs represent the mantissa (m). The formula to convert the compressed counts to true counts is as follows:

$$\text{COUNTS} = m \quad \text{if } e = 0,$$

and

$$\text{COUNTS} = [2 ** (e-1)] * [512 + m] \quad \text{if } 0 < e < 8.$$

Conversion of the decompressed counts into differential flux is accomplished by an equation of the form:

$$\text{Diff. Flux}(i) = [\text{Counts}(i) - \text{Counts}(16) \times K(i)] / \text{GF}(i) / .512$$

where  $i = 0, 17$ ,  
Counts(16) represents background counts,  
Counts(i) represents the counts for channel (i),  
K(i) are channel dependent constants,  
and GF(i) are the geometric factors used to convert to flux.

Data flags contained in the DPU57 unit are included in the THDB for possible use in data interpretation. These include the Ram Check Status (K), Format Mode (N), Sun Pulse Bit (S), Contents of TM (T), and Ram reload (R).

### 5.3 PARAMETER LIST

Differential flux for 17 electron channels (40keV-2.2MeV) is available every 0.512 s.

### 5.4 THDB DATA RECORD STRUCTURE

The THDB files for this sensor consist of a header record (in 32 bit integer form) followed by a series of data records.

THDB Data Records - Medium Energy Electrons data for 17 differential electron energy channels plus one background channel is stored in 16 bit words (two 16 bit words per 32 bit word). The vacant/flag word at the end of each record has the value 0 (for normal operations) or 1 (to indicate that a data gap follows due to the spacecraft telemetry mode being changed to CSM or LAS mode).

Each record has data accumulated over 4 telemetry frames (0.512 seconds). Dropout words within a spectrum are noted by 1's fill. If dropout occurs over a full spectrum, there are no fill. The data is simply missing.

#### HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (value is 70151)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-12	Vacant (Zero fill)

#### DATA RECORDS (32 bit words):

Word No.	Description
1	UT (milliseconds)
2	Compressed counts for E0 and E1
3	" " " E2 and E3
4	" " " E4 and E5
5	" " " E6 and E7
6	" " " E8 and E9
7	" " " E10 and E11
8	" " " E12 and E13
9	" " " E14 and E15
10	" " " E16 (background) and E17
11	Byte 3: vacant
	Byte 2: Telemetry Dropout flag (Value = 1 if dropout in this frame, normal value is 0)
	Byte 1: Bit 7 = Sync indicator; 0=sync ok, 1=sync mismatch
	Bit 6 = C (Calibration flag)
	Bit 5 = K (Ram check status)
	Bit 4 = N (Format mode)
	Bit 3 = S (Sun Pulse bit)
	Bit 2 = T (Contents of TM)
	Bit 1 = W (Ram Reload)
	Bit 0 = Telemetry flag. Normally 0; is set to 1 if a data gap follows due to a switch to CSM or LASSII telemetry mode.
12	Vacant

### 6.0 AFGL-701-5B ELECTRON-PROTON ANGLE SPECTROMETER (EPAS)

#### 6.1 INSTRUMENT DESCRIPTION



The Electron-Proton-Angle Spectrometer (EPAS), or sensor 701-5B, measures protons and electrons with emphasis on wide pitch angle coverage with good pitch angle resolution. The viewing angles and apertures of the instrument are such that electron pitch angle coverage is achieved between 0 and 120 degrees with respect to the spacecraft axis. Protons are measured in four directions. The combination of a special magnetic deflection system and a solid-state particle detection technique makes it possible to obtain simultaneous measurements for different pitch angles.

Protons are measured in the energy range 20 keV - 2 MeV, and electrons in the range 20 - 300 keV.

All particle detectors (ions: P 0 to P 3; electrons E 0 to E 9) are followed by charge sensitive preamplifiers, pulse amplifiers, pulse formers, and discriminators.

The proton telescopes produce three different sets of data: the count rates of the front detectors (P 0 to P 3), the count rates of the back detectors (U 0 to U 3), and coincidence counts of the front and back detectors. The count rates of the front detectors go to a "Proton Selector" unit which selects one of the four for energy analysis in the proton pulse height analyzer (PHA). This analysis is only carried out if a coincidence between front and back detectors has not occurred. These data are called differential count rates.

Simultaneously the count rates of the four front detectors are routed via discriminators to the data processing unit (DPU); these are called integral count rates.

The data lines from the ten electron detectors (E 0 to E 9) pass the "Electron Selector" which determines on which of the ten channel energy analysis is carried out in the "Electron PHA". The ten data lines are also routed via discriminators as integral count rates directly to the DPU.

The proton and electron PHA sort the count rates from one selected proton and electron detector into 12 and 15 different energy intervals, respectively.

Data for this sensor is acquired only when the spacecraft is operating in GTO telemetry mode.

## **6.2 REDUCTION PROCEDURES**

The prime telemetry data for this instrument is also readout by Aerospace DPU57. The time cycle duration for this DPU is 16 major frames (65.536 seconds). As noted in the 701-5A description, a 9 bit sync word is readout once every 8 minor frames. This sync word is used in locating the minor frames from which to extract the counts corresponding to the 14 point electron differential flux spectrum; the 12 point proton

differential flux spectrum; the integral flux values from the 10 electron sensors and 4 proton sensors; and the proton coincidence and background counting rates.

The 8 bit compressed counting rate data for the 14 point electron flux spectrum (E0-E13) follows a pattern of 2 words on the minor frame containing the sync word, followed by 12 words on the next minor frame. Thus, once sync is found, the alternating frame pattern is fixed. In addition, a four bit readout (DSE) identifies the detector from which the spectra was acquired. This 4 bit readout appears on alternating minor frames beginning with the frame containing the sync word. The 12 point proton spectrum data (P0-P11) is readout on every fourth telemetry frame. These 8 bit readouts are located on the third minor frame following the sync word. A two bit readout (DSP) identifying the detector from which the spectra was acquired appears six minor frames preceding the spectrum (i.e. it lags by one spectrum).

The 8 bit compressed counts readouts corresponding to integral flux from the 10 electron sensors (data values IDE0-IDE9) and 4 proton sensors (IDP0-IDP3) are located on the minor frame containing the sync word and the succeeding minor frame. The two minor frames which then follow contain no integral flux data. The pattern then repeats on a 4 minor frame cycle.

The 8 bit coincidence (PCOINC) and background count rates (PBKGD) for protons appear on the second frames following a sync word frame and every fourth frame thereafter.

The THDB has one record per four minor frames and contain the compressed counts (in byte form) from the two electron spectra and the associated detector numbers; the proton spectra and associated detector number; the 10 electron and 4 proton integral flux values; the proton coincidence and background counting rates; and selected discretes which may be useful in data interpretation. The bytes containing the compressed counts values are stored in 32 bit integers.

The instrument has a calibrate mode which is executable by uplink command. The duration of the calibration mode is for integral multiples of 16 major frames beginning on the frame for which the FORMAT/2 counter value is zero. This counter is a 7 bit readout located in word 8 of a minor frame containing the 9 bit sync word. A single flag bit is used to determine areas where the instrument is in calibrate mode.

For the 701-5B 8 bit compressed counts values, the 4 MSBs of the word represent the exponent (e) and the 4 LSBs represent the mantissa (m). The decompression algorithm is as follows:

$$\text{COUNTS} = m \text{ if } e = 0,$$

and

$$\text{COUNTS} = [ 2 ** (e-1) ] * [ 16 + m ] \quad \text{if } 0 < e < 16.$$

The 701-5B integral flux counts are converted to integral flux by means of a multiplication constant for each sensor.

The true counting rates for the spectra data are converted to differential flux by means of an equation of the form:

$$\text{DIFF FLUX}(I,J) = \text{CTS}(I,J) * G(I,J)$$

where I represents a channel number and J represents a detector number, CTS(I,J) represents true counts for channel I of the Jth detector, and G(I,J) are the multiplicative geometric factors. The spectra data points are simultaneously sampled. The time at which the sampling occurs is .256 seconds prior to readout.

### 6.3 PARAMETER LIST

Integral flux from 10 electron sensors is available every 0.512 seconds.

Integral flux from 4 proton sensors is available every 0.512 seconds.

From the 10 electron sensors, one sensor is selected and a 14 point differential flux spectrum (20keV-250keV) is produced every 0.256 seconds.

From the 4 proton sensors, one sensor is selected and a 12 point differential flux spectrum (30keV-20MeV) is produced every 0.512 seconds.

### 6.4 THDB DATA RECORD STRUCTURE

The THDB files for the AFGL 701-5B consist of a header record followed by a series of data records.

There is one data record per 0.512 seconds.

HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (70152)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-18	Vacant (Zero fill)

## DATA RECORDS:

### Word No.

- 1 UT (milliseconds)
- 2 Compressed counts:  
Byte 1:Electron integral flux IDE0  
Byte 2:Electron integral flux IDE1  
Byte 3:Electron integral flux IDE2  
Byte 4:Electron integral flux IDE3
- 3 Byte 1:Electron integral flux IDE4  
Byte 2:Electron integral flux IDE5  
Byte 3:Electron integral flux IDE6  
Byte 4:Electron integral flux IDE7
- 4 Byte 1:Electron integral flux IDE8  
Byte 2:Electron integral flux IDE9  
Bytes 3-4:Vacant
- 5 Byte 1:Proton integral flux IDP0  
Byte 2:Proton integral flux IDP1  
Byte 3:Proton integral flux IDP2  
Byte 4:Proton integral flux IDP3
- 6 Byte 1:Sensor number for first electron spectrum  
Byte 2:Sensor number for second electron spectrum  
Byte 3:Sensor number for proton spectrum  
Byte 4:Vacant
- 7-13 Compressed counts (in byte form) for the first 14 point electron spectrum followed by compressed counts (in byte form) for the second 14 point electron spectrum
- 14-16 Compressed counts (in byte form) for the 12 point proton spectrum
- 17 Byte 1:Compressed counts for proton coincidence counting rate;  
Byte 2:Compressed counts for proton background counting rate;  
Byte 3:Discrete information as follows:  
Bit 7 = Telemetry dropout flag (=1 if dropout occurred in the .512 second interval)  
Bit 6 = C (Calibration mode flag)  
Bit 5 = K  
Bit 4 = N  
Bit 3 = S  
Bit 2 = T  
Bit 1 = W  
Bit 0 = Telemetry flag. Normally = 0; is set to 1 if a data gap follows due to a switch to CSM or LASSII telemetry mode.  
Byte 4: Vacant
- 18 Vacant

### Notes:

1. Dummy fill (1 fill) is used for dropout within a spectrum.
2. If dropout occurs for a full .512 seconds resulting in loss of both electron spectrum and the proton spectrum, no fill takes place.

3. If dropout occurs such that the sensor number from which a spectrum is taken is lost, the sensor number is 1's filled.

## **7.0 AFGL-701-6 LOW ENERGY PLASMA ANALYZER (LEPA)**

### **7.1 INSTRUMENT DESCRIPTION**

The Low Energy Plasma Analyzer for CRRES is designed to measure the three dimensional distribution function of electrons and ions in the energy range from 10 eV to 30 keV and to determine where in the distribution function and at what frequency wave-particle interactions occur. Both the plasma sheet and the plasma injected into the inner magnetosphere during substorms are primarily composed of particles in this energy range, an energy range considered low compared to radiation belt particles. As such, the low energy plasma plays a major role in the dynamics of the inner magnetosphere. Since the particles serve as a source for the radiation belts, an understanding of this plasma and its interaction with the ambient waves and fields is necessary for the development of a dynamic radiation belt model.

Electrostatic analyzers of various geometries have been used for many years as the primary means of measuring both electrons and ions in the energy range from thermal energies to energies in the neighborhood of 50 keV. Many of these analyzers have been basically monodirectional, determining pitch angle effects by relying on the spin of the satellite or on a motor driven system.

The basic sensors of the experiment are two 260 degree spherical electrostatic analyzers. Each analyzer consists of two concentric spherical plates. The space between the plates, on one edge, is closed off except for the entrance aperture. Along the other edge is positioned a microchannel plate. The entrance aperture limits particle access to an angular fan of approximately 5.6 degree by 128 degree. A symmetric potential is applied to the plates. The electric field produced is such that for a fixed potential, only particles within a 3% energy band of the central energy defined by the potential have great circle trajectories within the space between the plates that intersect the microchannel plate. The focusing of the system is such that within the 128 degree angle defined by the entrance aperture, the particles' pitch angles are imaged onto the microchannel plate to an accuracy of less than 1 degree.

Particles which impact the microchannel plate produce an electron cascade, resulting in a measurable pulse. The position of such pulses along the microchannel plate is determined using a discrete anode system. Particle positions are sorted into 16, 8 degree zones spanning the 128 degree fan. In addition any one 8 degree zone can be sorted into 8, 1 degree zones in order to image the

atmospheric loss or source cones. The preamplified pulses from each 8 degree zone are also fed out in parallel to a particle correlator board. The particle correlator uses a high frequency clock to record the arrival times of each electron or ion within each 8 degree zone. An on-board microprocessor then uses this information to perform an autocorrelation to determine if there is high frequency bunching in the particle arrival times produced by wave-particle interactions. In addition, the correlator receives as input the AC signal from the electric field antenna. The correlator determines the zero crossing times of this signal and then cross correlates this with the particle timing data as an additional technique to identify wave-particle interactions taking place.

The number of voltage steps per sweep can be set between 1 and 128. The experiment normally operates such that thirty point spectra is taken twice a second, or a 120-point spectrum once every two seconds over the entire energy range from 10 eV to 30 keV. With each measurement telemetered as an 8 bit logarithmically compressed word, approximately 15 kilobits/second would normally be needed to readout the experiment plus the telemetry needed to readout the correlator results. In order to fit the data within the approximate 2.6 kilobit/second telemetry rate provided the experiment, a microprocessor is used to select a portion of the data. Ten different preset modes have been established for the experiment, representing different mixes of electron, ions, and correlator data.

The experiment receives, as a direct input, information on the orientation of the angular fan being sampled relative to the in situ magnetic field. This information is used to set the measurement sequence for several of the modes. For example, the magnetometer data establish which two 8 degree zones within each satellite spin contain the atmospheric loss cone. Within these zones, 30-point spectrum are recorded in 8, 1 degree zones to image the loss cone. In addition to the preset modes stored in Read Only Memory in the experiment, the sensor can be programmed from the ground after satellite launch to set up any other measurement sequence desired. Each measurement sequence is repeated each half spin of the satellite.

## 7.2 REDUCTION PROCEDURES

The LEPA package includes two sensor heads, one for electrons and one for ions, and it can be operated in multiple electron and ion modes. With each mode, a set of correlator data is included. The LEPA THDB is basically a pre-processed file designed for use with follow on analysis routines. Data from all LEPA modes is included in the THDB in half spin blocks, but in general, only data from 2 electron modes and one ion mode is pertinent for THDB analyses. The correlator data associated all modes is included in the THDB.

The LEPA data is defined in terms of zones and sectors. Each sensor head is capable of measuring particles within a fan of 128 degrees (zones) in declination and 5.64 degrees of azimuth (sectors). The 128 degree declination range for each sensor is divided into sixteen 8 degree zones. In addition, any of the 8 degree zones can be divided into 8 one degree zones. The counts for each spectral point are log compressed. Each spectrum consists of 30 points.

By ground command, combinations of electron/ion modes can be selected. The primary electron modes chosen for the THDB are the "Symmetry Plane / Loss Cone" (referred to as MSE1) and "Full angular coverage" (referred to as MSE3). The primary ion mode selected is "Full Angular Coverage" (ion mode MSI1). Through the LEPA command system, MODE0 data consists of the "Symmetry Plane/Loss Cone" mode for electrons and "Full Angular Coverage" for ions; MODE10 data consists of "Full Angular Coverage" for both electrons and ions. Thus, only MODE0 and MODE10 data is the prime LEPA data in the THDB. In addition to the LEPA data, these modes (as do all others) include output from the particle correlator. The correlator data is included in the THDB.

In Symmetry Plane/Loss Cone mode, data are taken in the electron distribution's symmetry plane, in all zones when the loss cone is within the measurement fan and in all zones when the symmetry plane intersects a pitch angle of 90 degrees. In this sequence, the magnetometer provides the data that allow the determination of the sector and zone that, twice within a spin, contains the magnetic field vector. For the two sectors containing the magnetic field vector, a 30 point spectrum is taken in each of the sixteen course zones and in eight 1 degree zones for the course zone containing the magnetic field vector. The plane containing the two intersections with the magnetic field and the 90 degree pitch angle points is determined and in the other sectors, a thirty point spectrum is retained only for the zone in this plane. For the two sectors in a spin for which the pitch angle of the particles in the symmetry plane is approximately 90 degrees, all course zones are sampled.

To summarize, the data acquired in "Symmetry Plane/Loss Cone" mode over a full spin consists of the following:

- a. Symmetry Plane: 60 sectors by 30 point spectrum per sector (1800 bytes/spin).
- b. Loss Cone: 16, 1 degree zones by 30 point spectrum per zone (480 bytes/spin).
- c. Loss Cone: 32, 8 degree zones by 30 point spectrum per zone (960 bytes/spin).
- d. 90 degree: 32, 8 degree zones by 30 point spectrum per zone (960 bytes/spin).

In "Full Angular Coverage" mode, all zones and sectors are sampled throughout the spin. In order to fit this data within the available telemetry, the data are averaged over contiguous

sectors and zones. A 30 point spectrum is taken, averaged over two eight degree zones and 4 sectors. Thus, within a spin, a 30 point spectrum is taken in eight 16 degree zones within each of the 22.5 degree sectors. In addition, the zone containing the loss cone is determined and imaged.

In summary form, the data acquired in "Full Angular Coverage" mode over a vehicle spin consists of the following:

- a. 8, 16 degree zones/sectors by sixteen 22.5 degree sectors/spin by 30 point spectrum per sector (3840 bytes per spin).
- b. 16, 1 degree zones by 30 point spectrum per zone (480 bytes/spin).

The locations of the 43 minor frame words (on telemetry designation S34) containing telemetry information for the LEPA are: 16, 18, 21, 24, 26, 28, 48, 50, 53, 56, 58, 60, 80, 82, 85, 88, 90, 92, 112, 114, 117, 120, 122, 144, 146, 149, 152, 154, 176, 178, 181, 184, 186, 208, 210, 213, 216, 218, 240, 242, 245, 248, and 250.

The LEPA data is accumulated in half spin blocks, and through a double-buffer system, one buffer is readout to telemetry while the other buffer is being filled. The half-spin data is asynchronously inserted into the telemetry stream. Data from all modes is extracted from the agency file, time tagged to the minor frame at the start of the half spin block, and stored in the THDB in half spin block form. For the purposes of THDB usage, only data from modes MODE0 and MODE10 should be considered by LEPA analysts. Each half spin block begins with a 64 byte header. The first 7 bytes of the header consist of sync words which, represented in hexadecimal, are: 4B, 49, 54, 43, 48, 45, and 4E (decimal values are 75, 73, 84, 67, 72, 69, and 78). The LEPA THDB routine searches the data stream and accumulates the half spin block starting at the first sync word and continue storing data up to but excluding the start of the next 7 word sync pattern. The number of bytes counted in each half spin block is included in the THDB data records. If the number of bytes counted between sync patterns exceeds 5600, a flag is placed in the data record indicating that caution must be used with the data from this record, and a new search for the 7 byte sync pattern is begun.

In addition to the half spin data readout for each of the modes, 16 bit sync words are inserted into the LEPA bit stream at 512 byte intervals. A summary table of the half spin block lengths (which include the header, LEPA data, and correlator data but DO NOT count the 16 bit sync bytes interlaced in the LEPA data stream) for each of the LEPA modes is given below:

MODE NUMBER	LENGTH IN BYTES
MODE 0 = MSE1+MSI1	4612 bytes



MODE 1 = MSE2+MSI2	4612 bytes
MODE 2 = MSE1+MSI4	4620 bytes
MODE 3 = MSE2+MSI4	4620 bytes
MODE 4 = MSE4+MSI3	4632 bytes
MODE 5 = MSE5+MSI4	4632 bytes
MODE 6 = MSE6+MSI4	4632 bytes
MODE 7 = MSE5	4768 bytes
MODE 8 = MSE6	4768 bytes
MODE 9 = MSE4+MSI4	4616 bytes
MODE10 = MSE3+MSI1	4672 bytes
MODE11 = Memory copy mode	4160 bytes
MODE12 = Upload mode	4160 bytes (maximum)
MODE13 = Analog readout mode	1984 bytes

Since the LEPA and correlator data is stored in the THDB in compressed counts form, the decompression algorithm required to obtain true counts involves an exponent E (the 3 MSBs of the 8 bit readout) and a mantissa (the 5 LSBs of the 8 bit readout). The formula is as follows:

$$\text{TRUE COUNTS} = (2^{**}E) * (M + 32) - 32.$$

### 7.3 PARAMETER LIST

The data for the 701-6 is accumulated over a half spin periods of the vehicle. Data from all modes is included in the THDB, but only data from modes MODE0 and MODE10 should be considered. The data from these two modes produce data sets from two of the electron modes and one ion mode. All spectra consist of 30 points. The correlator data associated with these electron and ion modes is included in the THDB. Additional words are included to explicitly define the mode number; the number of bytes in the LEPA half spin block, to provide an indicator of dropout in the half spin block; and to indicate that a data gap follows due to a telemetry mode switch to LASSII.

#### ELECTRONS MODES:

1. Symmetry plane - loss cone mode
  - a. 64 spectra in the magnetic field symmetry plane
  - b. 30 spectra for the sectors containing 90 degree pitch angle
  - c. 30 spectra for the sectors containing the loss cone
  - d. 16 spectra in 1 degree increments for the 2 zone-sector regions containing the loss cone
2. Full angular coverage mode
  - a. spectra averaged over 2 zone - 4 sector segments
  - b. 16 spectra in 1 degree increments for the 2 zone-sector regions containing the loss cone

#### ION MODE:

1. Full angular coverage mode (same as for electrons above)

**CORRELATOR:**

The data from the correlator is included at the full data rate of the output for these modes.

**7.4 THDB RECORD STRUCTURE**

The THDB for the LEPA consists of a header record followed by a series of data records containing half spin blocks of LEPA from all modes. Data records containing information from modes other than MODE0 and MODE10 should be ignored. In MODE0, the data consists of a header section, electron symmetry plane/loss cone data, ion full angular coverage data and correlator data. In MODE10, the data consists of electron and ion full angular coverage data along with correlator data. The LEPA data is stored in byte form (4 bytes per 32 bit word).

**HEADER RECORD (All words 32 bit integers)**

Word Number	Description
1	Experiment ID (7016)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-1410	Vacant (Zero fill)

**DATA RECORDS:**

Word Number	Description
1	UT (milliseconds) - at the start of the minor frame containing the LEPA sync word.
2	Minor frame word number containing the first of the seven LEPA sync words (1 to 43)
3	Data flags: Byte 1: Telemetry dropout indicator (0=no dropout, 1=dropout somewhere in this half spin block) Byte 2: Telemetry mode indicator (value is 0 for GTO and CSM modes; value is 1 the data in this record is dummy filled due to a telemetry mode switch to LASSII. A data gap (in time) follows. Additional information is written to this file only when the telemetry is switched back to GTO or CSM.)

Byte 3: Data over-run flag. Value is set to 1 if there were more than 5600 bytes between the 7 LEPA sync words which start a half spin block. The data in this record should be considered 'suspect' if the flag bit is set to 1.

Byte 4: Vacant

4	LEPA mode number
5	Number of data bytes in the LEPA half spin block.
6-1405	LEPA data from the half spin block stored in byte form. The number of half spin bytes is contained in word 5 of this record. All bytes in excess of that number should be ignored.
1406-1410	Vacant

The LEPA data contained in the half spin blocks for MODE0 and MODE10 is defined as below.

#### HEADER SECTION:

Byte	Description:
0-6	7 byte sync word
7-9	24 bit half spin counter (byte 7 =LSB, byte 9=MSB)
10	LEPA mode, HV attenuation mask, command status. bits 7-6 = telecommand error bit 5 = ion HV mask bit 4 = electron HV mask bits 3-0 = science mode
11	spare
12-13	EOT (end of transmission for last half spin (12=LSB)
14-15	EOI (end of information for this half spin (14=LSB)
16-17	Last command received or Mode B last byte plus 1 (16=LSB)
18	Magnetometer data 1
19-20	Magnetometer clock 1 (19=voltage, 20=sector)
21	Magnetometer data 2
22-23	Magnetometer clock 2 (22=voltage, 23=sector)
24	Sector imaged as loss cone sector (modes 0-4, 9-A) or starting sector for chorus imaging (modes 5-8)
25	Sector imaged as 90 degree sector (modes 0-4, 9-A) or starting zone for chorus imaging (modes 5-8).
26-27	Sun clock (26=voltage, 27=sector).
28	DR (sun clock divide ratio) Clock step in milliseconds = $(1024 + DR) / 625$ One half spin = 8192 clock steps upon reset, DR = 120 decimal.
29	MCP readout bits 7-4 = ion MCP level bits 3-0 = electron MCP level
30-31	A to D count, to be identified from half spin counter (30=LSB)

32-63 Background counts, one byte per sector, integrated over all energies. Ion counts are taken during even numbered sectors and electron counts during odd (sector number = address - 32). The summed counts are logged.

#### MODE0 HALF SPIN DATA BLOCK:

Offset	Description
0	Header (64 bytes)
64	Electron symmetry plane (900 bytes) Offset + $30*S + V$ where $S = 0, 1, 2, \dots, 29$ and does not get incremented for the loss cone or 90 degree sectors and where $V = 0, 1, 2, \dots, 29$ . Counts are logged.
964	Electron loss cone fine (240 bytes) Offset + $16*V + FZ$ where $V = 0, 1, 2, \dots, 29$ and where $FZ = 0, 1, 2, \dots, 7$ .
1204	Electron loss cone coarse (480 bytes) Offset + $16*V + Z$ where $V = 0, 1, 2, 3, \dots, 29$ and $Z = 0, 1, 2, \dots, 15$ . Counts are logged.
1684	Electron ninety degree - coarse (480 bytes) Same as electron loss cone coarse for this mode.
2164	Ion coarse mode (1920 bytes) Offset + $60*S + 8*V + [7-Z]$ where $S = 0, 4, 8, \dots, 28$ and where $V = 0, 1, 2, 3, \dots, 29$ and where $Z = 0, 1, 2, \dots, 7$ . Z labels the eight 16 degree zones; counts are logged sums over 4 sectors and two 8 degree zones for each value of V.
4084	Ion loss cone fine Same as electron loss cone fine for this mode.
4324	SPACE (Correlator data) (288 bytes)
4612	Data fill (60 bytes) This is not part of the LEPA bit stream. The fill is inserted to maintain fixed length records in the THDB.

#### MODE10 HALF SPIN DATA BLOCK:

Offset	Description
0	Header
64	Electron coarse mode (1920 bytes) Offset + $60*S + 8*V + [7-Z]$ where $S = 0, 4, 8, \dots, 28$ and where $V = 0, 1, 2, \dots, 29$ and where $Z = 0, 1, 2, \dots, 7$ . Z labels the eight 16 degree zones and the counts are logged averages over 4 sectors and two 8 degree zones for each value of V.
1984	Electron loss cone fine (240 bytes) Same as MODE0.

2224	Ion coarse mode (1920 bytes) Same as MODE0.
4144	Ion loss cone fine (240 bytes) Same as MODE0
4384	SPACE (Correlator) (288 bytes)

**Notes:**

1. As an additional precaution against telemetry dropouts, the on-board LEPA software inserts a 2 byte sync pattern into the data stream at intervals of 512 bytes. Numbering the bytes in a half spin from 0, bytes  $511+(N*512)$  and  $512+(N*512)$  where  $N = 0, 1, 2, 3, \dots, 8, 9$  comprise a series of 16 bit sync words of the form AAAM (hex) where  $M = N + 1$ . The address offsets listed above for the MODE0 and MODE10 data do NOT reflect the presence of the sync words.
2. For a given half spin, the time TB of the beginning of the half spin sync word can be determined from the time of the minor frame at the start of a half spin block and the position of the sync word in the minor frame. Once TB is known, the data in the half spin can be time tagged as follows. The length of the half spin in milliseconds is

$$DT = 8192 * ((1024 + DR) / 625)$$

where DR is the clock divide ratio located at header offset 28. The data then has been acquired starting at time

$$TR = TB - DT$$

and within the buffer each sector begins at

$$TS = TR + S * (DT / 32).$$

If finer time resolution is desired, the voltage step interval can be derived as

$$TV = TS + V * (DT/1024).$$

## **8.0 AFGL-701-7A RELATIVISTIC PROTON DETECTOR**

### **8.1 INSTRUMENT DESCRIPTION**

As the name of the experiment implies, the immediate objective of the Relativistic Proton Detector is to measure the energy spectra and pitch angle distributions of relativistic protons trapped in the inner Van Allen belt.

The Relativistic Proton Detector design is based on a sensor flown aboard the Pioneer 10 and 11 spacecraft to Jupiter. The primary sensor is a Cerenkov radiator viewed by a photomultiplier tube. Two copies of this sensor with different radiators extend the energy range response over the Pioneer detectors. One of the radiators is an alcohol- water mixture as flown aboard the Pioneer 10/11 spacecraft. The other radiator is fused silica. The alcohol-water radiator has an index of refraction of 4/3 and responds to protons with energies above 440 MeV. The fused-silica radiator has an index of 3/2 and responds to protons above 320 MeV.

In addition to the Cerenkov radiators, the AFGL-701-7A sensor includes another detector system from the Pioneer 10/11 experiment which is to measure electrons. This system consists of two detectors: an electron scatter detector (E) for electrons with energies above 200 MeV, and a heavily shielded minimum-ionizing detector (M) for penetrating electrons (>35 MeV) and protons (>80 MeV).

Data for this sensor is acquired only when the spacecraft is operating in GTO telemetry mode.

## 8.2 REDUCTION PROCEDURES

The data from this AFGL 701-7A instrument is readout by the Aerospace DPU57. There are 2 Cerenkov detectors (alcohol and silica) each of which produces 4 points every 1.024 seconds. In addition, there are 2 other detectors (Electron Scatter Detector and Minimum Ionizing Detector) each of which produces 4 points per 2.048 seconds. Sensor outputs are in 8 bit compressed form.

The DPU nomenclature for the sensor outputs is:

Alcohol (CA0-CA3)

Silica (CS0-CS3)

Electron Scatter Detector (RE(0,2) - RE(1,3))

Minimum Ionizing Detector (RM(0,2) - RM(1,3))

The data for these sensors is obtained by taking the full energy range and breaking it into 4 energy bands. Through internal DPU logic, the values placed into the telemetry represent the flux values in each of the energy bins. The points for the Cerenkov detectors represent the counts accumulated in each energy bin over the previous 1.024 seconds. For the other 2 detectors, the data represents the counts accumulated in each energy bin over the previous 2.048 seconds.

There is no calibrate mode for the 701-7A, but the instrument can be commanded into photometer mode. When in photometer mode, all data readout to telemetry is from the four photometers. The photometer data is included in the THDB.

The channels being readout initiate on a minor frame containing a sync word. For the 2.048 second detector rates, the first channel is identified by using the sync word in conjunction with the FORMAT/2 counter.

The THDB data records contain data accumulated over 16 minor frames (2.048 seconds). Data stored consists of compressed counts (in byte form) for two four point spectra from the Cerenkov detectors ( 1 and 2); and one set of four point spectra from the Electron Scatter detector and the Minimum Ionizing detector (detectors 3 and 4).

For the 701-7A 8 bit compressed counts, the 4 MSBs of the word represent the exponent (e) and the 4 LSBs represent the mantissa (m). The decompression algorithm is as follows:

$$\text{COUNTS} = m \text{ if } e = 0,$$

and

$$\text{COUNTS} = [ 2 ** (e-1) ] * [16+ m ] \text{ if } 0 < e < 16.$$

The counts readout by the instrument represent differential flux. They should be converted to integral flux. Further, 4 new channels have been defined for electron integral flux with energies greater then defined levels.

For CA, CS, RE, and RM - convert to integral flux as follows (where CH represents each of the 4 data sets above):

$$\begin{aligned} \text{CH0}' &= \text{CH0} + \text{CH1} + \text{CH2} + \text{CH3} \\ \text{CH1}' &= \text{CH1} + \text{CH2} + \text{CH3} \\ \text{CH2}' &= \text{CH2} + \text{CH3} \\ \text{CH3}' &= \text{CH3}. \end{aligned}$$

These give integral flux values for the Cherenkov (alcohol and silica), the Electron Scatter Detector , and the Minimum Ionizing Detector.

Then, the new ELECTRON channels are defined as follows:

$$\begin{aligned} e > 160\text{keV} &= \text{RE0}' - \text{RM0}', \quad \text{GF}=.013\text{E} \\ e > 255\text{keV} &= \text{RE1}' - \text{RM0}', \quad \text{GF}=0104 \\ e > 460\text{keV} &= \text{RE2}' - \text{RM1}', \quad \text{GF}=0057 \\ e > 875\text{keV} &= \text{RE3}' - \text{RM2}', \quad \text{GF}=.0025. \end{aligned}$$

The new values can be divided by the geometric factors to get integral flux although the geometric factor for the 875keV channel is poorly known. Units for the geometric factors are  $\text{cm}^2\text{sr}$ .

### 8.3 PARAMETER LIST

There are four sets of 4 point proton spectra. Two of the sets readout the 4 points every 1.024 seconds; the other two sets readout their 4 points every 2.048 seconds. The counts from all 16 readouts represent flux. The instrument discretizes and a data flag are also included in the THDB.

#### 8.4 THDB DATA RECORD STRUCTURE

The THDB files for the AFGL 701-7A consist of a header record followed by a series of data records. There is one data record per 16 telemetry frames (2.048 seconds)

HEADER RECORD (All words 32 bit integers):

Word Number	Description
1	Experiment ID (value is 70171)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-10	Vacant (Zero fill)

DATA RECORDS:

Word No.

1	UT (milliseconds)
2	Byte 1:compressed counts from CA0 - 1st spectrum
	Byte 2:compressed counts from CA1 - 1st spectrum
	Byte 3:compressed counts from CA2 - 1st spectrum
	Byte 4:compressed counts from CA3 - 1st spectrum
3	Byte 1:compressed counts from CS0 - 1st spectrum
	Byte 2:compressed counts from CS1 - 1st spectrum
	Byte 3:compressed counts from CS2 - 1st spectrum
	Byte 4:compressed counts from CS3 - 1st spectrum
4	Byte 1:compressed counts from CA0 - 2nd spectrum
	Byte 2:compressed counts from CA1 - 2nd spectrum
	Byte 3:compressed counts from CA2 - 2nd spectrum
	Byte 4:compressed counts from CA3 - 2nd spectrum
5	Byte 1:compressed counts from CS0 - 2nd spectrum
	Byte 2:compressed counts from CS1 - 2nd spectrum
	Byte 3:compressed counts from CS2 - 2nd spectrum
	Byte 4:compressed counts from CS3 - 2nd spectrum
6	Byte 1:compressed counts from RE0
	Byte 2:compressed counts from RE1
	Byte 3:compressed counts from RE2
	Byte 4:compressed counts from RE3
7	Byte 1:compressed counts from RM0
	Byte 2:compressed counts from RM1
	Byte 3:compressed counts from RM2



8           Byte 4: compressed counts from RM3  
           Byte 1:  
             Bit 7 = M ( 1 = Photometer data)  
             Bit 6 = C discrete  
             Bit 5 = K discrete  
             Bit 4 = N discrete  
             Bit 3 = S discrete  
             Bit 2 = T discrete  
             Bit 1 = W discrete  
             Bit 0 = CSM flag. (normally 0; value is set to 1  
                                   if data gap follows due to CSM or LAS)  
           Byte 2: Telemetry dropout flag (value is set to 1 if  
                                   there is telemetry dropout in the 2.048  
                                   second interval covered by this record  
                                   resulting in dummy fill of any values)  
           Bytes 3-4: Vacant  
 9-10       Vacant  
  
 Note:      Counts from each detector are arranged in order of  
             increasing energy.

## 9.0 AFGL-701-7B PROTON SWITCHES

### 9.1 INSTRUMENT DESCRIPTION

The proton switch consists of two single detector units in an omnidirectional configuration. These units measure the fluxes of protons in the energy ranges from 20-80 MeV.

The two omnidirectional sensors use small, cubical, lithium-drifted silicon detectors centered under a hemispherical aluminum bubble. The lower proton energy threshold of each of the sensors is determined primarily by the thickness of the hemispherical bubbles. Protons are separated unambiguously from electrons by setting the discriminator level well above the maximum energy an electron can deposit in the small semiconductor detector. The fact that  $dE/dx$  (energy loss per unit path length) is much greater for protons than for electrons (in the energy range of geophysical interest) is utilized. The absence of electron contamination in the proton channels is verified by electron irradiation of the sensors.

Data for this sensor is acquired only when the spacecraft is operating on GTO telemetry mode.

### 9.2 REDUCTION PROCEDURES

Proton switch telemetry data consists of counts representing flux for each of the two omnidirectional sensors. One of the four 8 bit values is readout by DPU57 every 8 minor frames (1.024

seconds). Thus, the full set of 4 readouts is acquired once per major frame. The word location within the DPU57 bit stream is fixed on the fourth frame following a 9 bit sync word. The parameter being readout is determined by use of the 7 bit FORMAT/2 counter. The correlation between the FORMAT/2 counter, the DPU designation and the lower and upper energy thresholds for each sensor is as follows:

MOD(FORMAT/2,4)	DPU Designation	Approximate Energy Range
0	PSU(0)	50-75 MeV
1	PSU(1)	20-50 MeV
2	PSL(0)	50-105 MeV
3	PSL(1)	20-83 MeV

The THDB data records contain the 4 compressed counts readouts each of which is stored in a 32 bit integer word. There is one record per 4.096 seconds.

For the 701-B 8 bit compressed counts data, the 4 MSBs of the word represent the exponent (e) and the 4 LSBs represent the mantissa (m). The decompression algorithm is as follows:

$$\text{COUNTS} = m \text{ if } e = 0,$$

and

$$\text{COUNTS} = [2^{(e-1)}] * [16 + m] \text{ if } 0 < e < 16.$$

The formula for the conversion of decompressed counts to flux (in  $P/\text{cm}^2\text{-sec-ster}$ ) for channel i is:

$$\text{FLUX}(i) = \text{COUNTS}(i) / (\text{AP} * \text{GF}(i))$$

where AP is the accumulation period (nominally 4.096 seconds) and GF(i) is the geometric factor for channel i.

Preliminary values of GF(i) for the various channels are:

PSU(0)	.352 $\text{cm}^2\text{-ster}$
PSU(1)	.260 $\text{cm}^2\text{-ster}$
PSL(0)	.272 $\text{cm}^2\text{-ster}$
PSL(1)	.376 $\text{cm}^2\text{-ster}$

### 9.3 PARAMETER LIST

Proton flux from the 2 channels of each sensor is available at a rate of once per major frame.

Instrument discretes and a flag word (to indicate CSM or LASSII telemetry mode) are included at the major frame rate.

#### 9.4 THDB DATA RECORD STRUCTURE

The THDB files for the AFGL 701-7B consist of a header record followed by a series of data records. The header record is in 32 bit positive integer form. There is one data record per 4.096 seconds

HEADER RECORD (All words 32 bit integers):

Word Number	Description
1	Experiment ID (70172)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-8	Vacant

DATA RECORDS:

Word No.

1	UT (milliseconds)
2	Compressed counts for integral flux PSU(0) (50-75MeV)
3	Compressed counts " " " PSU(1) (20-50MeV)
4	Compressed counts " " " PSL(0) (50-105MeV)
5	Compressed counts " " " PSL(1) (20-83MeV)
6	Byte 1: Bit 7 = Vacant Bit 6 = C discrete Bit 5 = K discrete Bit 4 = N discrete Bit 3 = S discrete Bit 2 = T discrete Bit 1 = W discrete Bit 0 = Telemetry flag (normally 0; is set to 1 if data gap due to CSM or LAS follows)
	Byte 2: Telemetry dropout flag (value is 1 if any of the values stored were dummy filled due to telemetry dropout).
	Bytes 3-4: Vacant
7-8	Vacant

#### 10.0 AFGL-701-8,-9 PROTON TELESCOPE (PROTEL)

##### 10.1 INSTRUMENT DESCRIPTION

The objective of the Proton Telescope (PROTEL) is to make well-calibrated, high resolution measurements of 1- 100 MeV protons. PROTEL consists of two sensor head assemblies and a data

processing unit (DPU). The low energy sensor head measures 1-9 MeV protons in 8 contiguous energy channels. The high energy sensor head measures 6-100 MeV protons in 16 contiguous energy channels. The entire 24 point spectrum is returned once per second. PROTEL monitors the major energy contributors to the radiation belts for use in both static and dynamic radiation belt models.

Operation of this instrument is controlled by an experiment command system. A sixteen bit command word supplied by the spacecraft is decoded into a four by eight matrix of static on-off command elements, with each commandable function controlled by one or more command elements. The more critical functions utilize several redundant elements.

## 10.2 REDUCTION PROCEDURES

The PROTEL telemetry consists of a 24 point proton differential flux spectrum, 10 heavy ion dose measurements, 12 singles readouts from the high energy sensor head, and 9 singles readouts from the low energy sensor head, command state bits, and instrument housekeeping analogs. The prime science data from this instrument is readout 10 times per minor frame on designation S35 which is located on minor frame words 23, 27, 55, 59, 87, 119, 151, 183, 215, and 247 in GTO and CSM telemetry formats. In LASSII telemetry format, the word locations change to minor frame words 57, 59, 121, 123, 169, 185, 187, 201, 249, and 251. A full set of detector (S35) readouts is obtained every 8 minor frames beginning on sub-frames 0, 8, 16, and 24. All minor frame words are eleven bits comprised of a 4 bit exponent followed by a 7 bit mantissa. Minor frames 0 through 6 (mod 8) have seven science words (11 bits) followed by three spare bits; minor frame 7 (mod 8) has six science words followed by 14 spare bits. The sequence of words within the 8 minor frames is as follows:

### SUBFRAME DATA

- 0 High energy channels 1 through 7
- 1 High energy channels 8 through 14
- 2 High energy channels 15 and 16 followed by high energy singles channels D1A, D12A, D123A, D134A and D145A
- 3 High energy singles channels D6, Dr, D1, D2, D3, D4, D5
- 4 Low energy channels 1 through 7
- 5 Low Energy channel 8 followed by low energy singles channels D1A, D12A, D123A, D134A, D5, D1
- 6 Low energy singles channels D2, D3, D4 followed by four ion dose channels.
- 7 6 ion dose channels

The data from the S35 science words is extracted from the bit stream, decompressed into true counts, and stored in the THDB in 32 bit words. Thus one THDB data record represents 4.096 seconds. The THDB also includes the 8 command state bits and

bilevels, designations B29 and B30 (SC-14, SF19 and SF20); and the 17 instrument analogs (designations A221-A237 located on SC11 / SF15-31. The command state bits are used to determine periods when the instrument is in calibration mode. Analog A236 identifies the command state row. The remaining analog words are for instrument housekeeping data. The analogs and bilevels are stored in the THDB in their telemetry form (8 bit bytes).

The decompression algorithm to convert the 11 bit data (4 exponent bits, 7 mantissa bits) to true counts is as follows:

$$\text{TRUE COUNTS} = M * 2^E,$$

where M represents the mantissa and E represents the exponent.

For the 24 proton channels, the conversion from true counts to differential flux is by means of a multiplicative constant (geometric factor) for each channel. Thus,

$$\text{DIFF FLUX}(i) = \text{TCOUNTS}(i) * \text{GF}(i),$$

where TCOUNTS(i) is the true counts for proton channel(i), and GF(i) is the associated geometric factor.

The calibration procedure for the dose data is also by means of one multiplicative factor per channel. Thus,

$$\text{DOSE}(i) = \text{DCOUNTS}(i) * \text{F}(i),$$

where DCOUNTS(i) represents the decompressed counts for dose channel(i), and F(i) is the associated multiplicative factor.

### 10.3 PARAMETER LIST

The PROTEL parameter list consists of:

1. Differential flux for a 24 point proton spectrum (1-100MeV) is available at 1.024 seconds .
2. Heavy ion dose in 10 channels (1.4-100MeV) is available at 1.024 seconds.
3. Twelve singles readouts from the high energy sensor head every 1.024 seconds.
4. Nine singles readouts from the low energy sensor head every 1.024 seconds.
5. Instrument bilevel and analog data every 4.096 seconds.

### 10.4 THDB DATA RECORD STRUCTURE

The AFGL 701-8,-9 THDB files consist of a header record followed by a series of data records. Each data record is made up of data accumulated over a master frame (4.096 seconds).

#### HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (value is 70189)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-230	Vacant (Zero fill)

#### DATA RECORDS:

Word No.	Description
1	UT (Milliseconds)
2-9	Decompressed counts for the 8 LE differential proton spectra
10-25	Decompressed counts for the 16 HE differential proton spectra
26-35	Decompressed counts for the 10 heavy ion dose measurements
36-56	Decompressed counts for LE singles channels (D1A, D12A, D123A, D134A, D5, D1, D2, D3, D4) followed HE singles channels D1A, D12A, D123A, D134A, D145A, D6, Dr, D1, D2, D3, D4, D5.
57-111	Repeat the order of words 2-56 for the next 1.024s.
112-166	" "
167-221	" "
222-226	Bilevels, analogs, and dropout flag in byte form and in the order B29, B30, A221-A237, dropout flag.
227-230	Vacant

#### Notes:

- 1 The dropout flag is set to 1 if there is dropout anywhere within the master frame.
2. Dropout within a spectrum is 1 filled.

### 11.0 AFGL-701-11A MAGNETOSPHERIC ION COMPOSITION SENSOR (MICS)

#### 11.1 INSTRUMENT DESCRIPTION

The objective of the SPACERAD Mass Composition Instruments is the unambiguous determination of the composition of the plasma and energetic particle populations of the Earth's Van Allen radiation

belts over the range of 40 eV/Q to 15 MeV per ion in order to identify mechanisms by which these charged particles are energized and transported from their parent source populations to the magnetosphere.

The Mass Composition Instruments incorporate three types of sensor systems: the Low Energy Magnetospheric Ion Composition Sensor (LOMICS), the Magnetospheric Ion Composition Sensor (MICS), and the Heavy Ion Telescope (HIT). Each of these performs a multiple-parameter measurement of the composition of magnetospherically trapped and transient ion populations over a combined energy range from 40 eV/Q to 15 MeV per ion (a range of over 5-1/2 orders of magnitude) and for elements from hydrogen through iron.

The MICS sensor uses a conically-shaped electrostatic analyzer, a secondary-electron generation/detection system, and a solid state detector to measure the energy, time-of-flight, and the energy per charge of the incident ion flux. These three parameters permit a unique determination of the ion charge state, mass, and incident energy over the energy range from approximately 30 keV/Q to 400 keV/Q.

Data for this sensor is acquired only when the spacecraft is operating in GTO telemetry mode.

## 11.2 REDUCTION PROCEDURES

The MICS data is readout to telemetry on designation S31 which contains the output from DPUA. S31 is located on minor frame words 32, 33, 34, 35, 96, 97, 98, 99, 160, 161, 162, 163, 224, 225, 226, and 227.

The DPU has a 9 bit sync word on minor frame word 32, and the MSB of word 33 of every eighth minor frame. The sync word is followed by a 7 bit FORMAT/2 counter which identifies the location of the DPU data within the 65.536 second (16 major frame) cycle of the instrument. By initially dividing the FORMAT/2 counter by 2, it should cycle from 0 to 63. This counter is, in effect, a subframe counter.

During each cycle, the instrument accumulates counts in a 16x32 matrix of m vs. m/q values. The counts readout from the matrix were simultaneously accumulated in each matrix element over the previous 16 major frame period.

In addition, a page of 8 m/q values is selected for energy analysis.

In normal mode, the energy analysis (approx. 30 kev/q to approx. 400 kev/q) produces a 32 point energy spectrum for each m/q every 8.192 seconds (2 major frames). In auroral mode, the same m/q values are selected, but 16 point energy spectra are acquired

every 4.096 seconds by taking every other energy step. A discrete (EPG) located on word 34 of the frame containing the 9 bit sync word is used to distinguish normal and auroral modes. When EPG is equal to 0, MICS is in normal mode; when EPG equals 1, MICS is in auroral mode. The spectra values are not simultaneously sampled; the time difference between points is .256 seconds. The spectra values are stored in DPUA words R0-R7. The energy step at which the spectra values are associated is located in DPUA value ESASTEP. The ESASTEP value should be in sync with the beginning of a FORMAT/2 counter, i.e. on the minor frame for which FORMAT/2 = 0, the ESASTEP should also be 0.

The instrument memory can hold 8 tables of 8 m/q values to be selected for analysis. Tables can be selected by uplink command. Moreover, table values can be changed by reprogramming memory. A three bit readout (R-PRG) located on minor frame word 33 of the 6th frame following a sync word frame identifies the table number selected for energy analysis.

The data for DPUA is on telemetry designation S31 located on 16 minor frame words 32, 33, 34, 35, 96, 97, 98, 99, 160, 161, 162, 163, 224, 225, 226, and 227. Blocks of DPUA data are readout over 8 minor telemetry frames (1.024 seconds).

The word descriptions for DPUA are as follows:

NAME	BITS	TYPE	DESCRIPTION
ALPHA	8	R	Alpha (helium ion) counting rate
C	1	S	Sensor calibrate status; 0:off, 1:on
COMMAND VER.	16	S	Echo of 16 bit ser. dig. cmd. recd from S/C
DCR	8	R	Diagnostic sensor coincidence rate
DPU HK	8	A	Analog data subcom. Position given in SUBCTR
ENERGY	7	E	Direct event energy pulse height, most significant 7 of 8 bits.
EPG	1	S	ESA program: 0=Normal 32 step, 1=Auroral 16 step
ESASTEP	5	S	ESA step number (0-31).
ETEB	4	E	Least sig. ENERGY (e) and TOF (t) bits as:00te
FORMAT/2	7	S	Defines position in major frame. Counts from 0-126 (in steps of 2).
FSR	8	R	Diagnostic sensor front detector singles.
HV MONITOR	8	A	Analog monitor of ESA voltages.
K	1	S	RAM check status flag. 0=passed; 1=failed.
M vs. M/Q(i)	8	R	Matrix scalar elements. i=0,511
M/Q	5	E	Direct event mass per charge group identifier.
MASS	4	E	Direct event mass group identifier.
MICS HK	8	A	Sensor housekeeping data, analog and status.



MSS	8	R	Sensor coincidence rate
NPR	1	S	No direct event priority. 0:Priority table, 1:Last event is output.
P	8	R	Proton counting rate.
R0-R7	8	R	Rate scalars from event analysis.
R-PRG	3	S	Rate scalar program. Defines contents of R0 - R7.
SN	1	S	Format mode. 0:Normal mode. 1:Special test mode.
SUBCTR	4	S	Counter for position in the DPU analog subcom.
SUN	1	S	Sun pulse bit; 0:No sun pulse, 1:Sun pulse recd.
SYNC WORD	9	S	Format/2 sync. word. Value=101001010.
TCR	8	R	Diagnostic sensor coincidence rate.
TM	1	S	Defines contents of TM. 0:Sensor data.
TOF	9	E	Direct event time-of-flight pulse height, most significant 9 of 10 bits.1
WR	1	S	S=1 if RAM was reloaded from ROM due to a detected fault.
Z	1	S	Subcommutated status flag for VVPS, HVPS, Safe/Arm status.

#### Data Types:

R:8 bit compressed data

S:Status bits, bytes, or words.

A:Analog bytes convertible to engineering units.

E:Direct event data (pulse heights, mass groups, etc.)

The frame layout for DPUA is depicted on the following page.

The pattern is repeated every 1.024 seconds. DPU A also has a Special Test Mode, Memory Dump Mode, and a Fixed TM data Mode. These modes are not used for normal science data and are not depicted.

Due to the complexity of algorithm development, the THDB contains the full set of DPUA data on a major frame by major frame basis. Flag words are included to indicate telemetry dropout and for a telemetry mode change from GTO to CSM or LASSII.

For the 701-11A, 701-11B and 701-11C 8 bit compressed counts, the 4 MSBs of the word represent the exponent (e) and the 4 LSBs represent the mantissa (m). The decompression algorithm is as follows:

$$\text{COUNTS} = m \text{ if } e = 0,$$

and

$$\text{COUNTS} = [ 2 ** (e-1) ] * [ 16 + m ] \text{ if } 0 < e < 16.$$

Data included in the MICS THDB files is for normal or auroral mode periods only.

**CRRES TELEMETRY FORMAT - DPU A  
NORMAL MODE - 02APR85 (REV C)**

		WORD 32 (96,160,224)	WORD 33 (97,161,225)	WORD 34 (98,162,226)	WORD 35 (99,163,227)
FMT	FRM				
0	0	SYNC = 101001010	FORMAT/2 CTR	1 TM EPG ESASTEP	HV MONITOR
	1	FSR	DCR	TCR	MSS
	2	PROTON	ALPHA	TOF	ENERGY
	3	R0	R1	TOF	ENERGY
	4	R2	R3	TOF	ENERGY
	5	R4	R5	TOF	ENERGY
	6	R6	R7	TOF	ENERGY
	7	M vs M/Q 0	M vs M/Q 1	TOF	ENERGY
1	0	MICS HK (A)	MICS HK (B)	0 K C ESA STEP	HV MONITOR
	1	FSR	DCR	TCR	MSS
	2	PROTON	ALPHA	TOF	ENERGY
	3	R0	R1	TOF	ENERGY
	4	R2	R3	TOF	ENERGY
	5	R4	R5	TOF	ENERGY
	6	R6	R7	TOF	ENERGY
	7	M vs M/Q 2	M vs M/Q 3	TOF	ENERGY
2	0	COMMAND VERIFICATION		0 SUN SN ESASTEP	HV MONITOR
	1	FSR	DCR	TCR	MSS
	2	PROTON	ALPHA	TOF	ENERGY
	3	R0	R1	TOF	ENERGY
	4	R2	R3	TOF	ENERGY
	5	R4	R5	TOF	ENERGY
	6	R6	R7	TOF	ENERGY
	7	M vs M/Q 4	M vs M/Q 5	TOF	ENERGY
3	0	DPU HK	SUBCTR WR R-PRG	0 Z NPR ESASTEP	HV MONITOR
	1	FSR	DCR	TCR	MSS
	2	PROTON	ALPHA	TOF	ENERGY
	3	R0	R1	TOF	ENERGY
	4	R2	R3	TOF	ENERGY
	5	R4	R5	TOF	ENERGY
	6	R6	R7	TOF	ENERGY
	7	M vs M/Q 6	M vs M/Q 7	TOF	ENERGY

### 11.3 PARAMETER LIST

The 701-11A THDB contains the full set of DPUA data from the instrument.

The 701-11A Instrument memory holds 8 tables of constituents; each table designates 8 constituents for analysis. Tables can be removed and replaced by new tables by uplink command.

Derivable parameters from the DPU include the following:

1. Page ID number
2. The 16 (mass) by 32 (m/q) matrix of counts accumulated by each matrix element every 65.536 seconds. This information is stored in byte (8 bit PCM) form in the THDB.
3. In normal mode, 8 m/q values are selected for energy analysis (nominally 30 keV/g to 400 keV/q) and a 32 point energy spectrum is produced every 8.192 seconds (2 major frames); in auroral mode, 8 m/q values are selected and a 16 point energy spectrum is produced every 4.096 seconds. The spectral data is in 8 bit compressed form in the THDB. Values of m/q to be included on each page are H+, He+, He++, O+ and O++. A code word to indicate normal or auroral mode is included on the file.
4. DPUA discretes and a telemetry mode indicator are included.

### 11.4 THDB DATA RECORD STRUCTURE

The THDB file consist of a header record followed by a series of data records containing the DPUA data. There is one data record per major frame (4.096 seconds). The DPUA telemetry data is stored in byte form.

HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (701111)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-130	Vacant (Zero fill)

Word No.

1	UT (ms)
2-5	DPUA data from telemetry minor frame 0
6-9	DPUA data from telemetry minor frame 1

10-13    DPUA data from telemetry minor frame 2  
 .  
 .  
 .  
 126-129    DPUA data from telemetry minor frame 31  
 130    Byte 4 (MS BYTE):TLM mode indicator  
       Bit 0 (LSB) = Telemetry indicator. Value is 0 when  
       spacecraft TLM is in GTO mode. Value is set to 1  
       when a data gap follows due to a switch to either  
       CSM or LASSII modes.  
       Byte 3:Dropout indicator  
       Bit 0 = 1 if there is 1's fill due to telemetry  
       dropout anywhere in this record.  
       Bytes 2 and 1 are vacant.

**Notes:**

1. In auroral mode the "32 point spectra" values are replaced by two successive 16 point spectra values for an effective rate of 4.096 seconds per spectrum.
2. The word order for the matrix values is:  
 (((M(i),MQ(j)),i=0,15),j=0,31).

**12.0 AFGL-701-11B LOW ENERGY MAGNETOSPHERIC ION COMPOSITION SENSOR (LOMICS) AND AFGL 701-11C HEAVY ION TELESCOPE (HIT)**

**12.1 INSTRUMENT DESCRIPTIONS**

The LOMICS and HIT instruments time share the same data processing unit. Data for these sensors is acquired only when the spacecraft is operating in GTO telemetry mode. A brief description of each instrument follows:

- A. LOMICS (Low Energy Magnetospheric Ion Composition Sensor). LOMICS consists of a 90 degree spherical section analyzer, a post-acceleration voltage of 10 keV, followed by multiple time-of-flight analyzers. The time-of-flight (TOF) mass analysis technique is usually restricted to high energy particles that undergo relatively little scattering and energy loss in generating start and stop signals. However, by post-accelerating energy/charge analyzed ions through a -10.0 keV potential and using very thin foils (approximately 1 g sq cm), it is possible to perform time-of-flight analysis on low-energy (approximately eV) ions. The electronics within the HMSB box are time-shared with the HIT sensor.
- B. HIT (Heavy Ion Telescope). The HIT sensor uses a three-element solid state detector telescope to measure the rate of energy loss, the ion incident energy, and its Time-of-

Flight. These three parameters permit a unique determination of the ion mass, elemental identification and incident energy over the energy range from 100 keV per ion to 15000 keV per ion.

## 12.2 REDUCTION PROCEDURES

These two instruments time share the same Aerospace DPU (DPUB). As with the MICS DPU, DPUB also has a cycle time of 16 major frames. The DPUB mode flag is used to determine the instrument mode. Within each instrument cycle, data from only one of the instruments is present. The standard operational mode cycles between HIT and LOMICS every 16 major frames, although other operational modes are possible. Data from this DPU is read out 20 times per minor frame on telemetry designation S33 (located on minor frame word numbers 0, 1, 2, 3, 4, 64, 65, 66, 67, 68, 128, 129, 130, 131, 132, 192, 193, 194, 195, and 196).

The THDB for this DPU consists of 4.096 second time tagged blocks of DPB data along with a dropout flag indicator and a CSM/LASSI flag. This data base should facilitate the input of DPUB data into further processing routines for HIT and LOMICS as algorithm development evolves.

For this data base, the telemetry data is retained in compressed form. All 8 bit telemetry values are stored in their original PCM byte form.

The information which follows should help facilitate the development of follow on analysis routines.

The discrete M is used to determine whether the data is from LOMICS (M=0) or HIT (M=1). Data from Normal mode (discrete N=0) can be deduced by the discrete N having the value of zero. When routine processing of the THDB information occurs, only sensor data (discrete T=0) should be used. In addition, periods where N=1 or T=1 should be ignored.

The DPU outputs a 9 bit sync word every 8th minor frame along with a FORMAT/2 counter which is used to identify position within the 16 major frame cycle. The FORMAT/2 counter cycles from 0 to 126 in steps of 2. Thus, by dividing the value by 2, the position in the 64 second sequence can be determined. THDB data records begin with the data from the telemetry minor frame containing the sync word.

Telemetry word information contained on DPU B is as follows:

NAME	BITS	TYPE	DESCRIPTION
COMMAND VERIF.	16	S	Echo of 16 bit ser. dig cmd. recd by DPU
D	1	S	Direct event priority. 0:First in,1:priority

DE	5	E	HIT direct event energy loss pulse height
E	8	E	HIT direct event energy pulse height
E/Q	5	E	LOMICS ESA E/Q pulse height
ESA	8	A	Analog monitor of LOMICS ESA voltage
FORMAT/2	7	S	Defines master position. 0-126 in steps of 2
HID(i)	8	R	HIT ID RAM scalar data. i=0,11
HR0-HR11	8	R	HIT event analysis RAM scalar data. 12 scalars
HS0-HS5	8	R	HIT diagnostic counting rates from sensor
HSK(i)	8	A	Analog data subcom from the DPU
ID	2	E	LOMICS detector ID number
K	1	S	RAM check status. 0:check passed,1:check failed
LS0-LS5	8	R	LOMICS diagnostic counting rates from sensor
LR0-LR5	8	R	LOMICS event analysis rate scalar data
M	1	S	Mode flag. 0:LOMICS, 1:HIT
MATRIX(i)	8	R	Matrix elements, i=0,511, for HIT or LOMICS
M/Q	5	E	LOMICS direct event mass per charge group ID. $M/Q = 2*QH+QL$ .
MASS	4	E	Direct event mass group identifier for HIT
N	1	S	Format. 0:Normal mode, 1:Special test mode
QH	4	E	Most significant 4 bits of M/Q for LOMICS direct event.
QL	1	E	Least significant bit of M/Q for LOMICS direct event
R-PRG	4	S	Rate scalar program. Defines contents of LR(i) and HR(i).
SENSOR STATUS	16	S	Sensor status flags as rec'd in reflected inst.
SU	1	S	Sun pulse bit. 0:No sun pulse, 1:sun pulse recd
SYNC WORD	9	S	FORMAT/2 sync word. Value=101101010
T	1	S	Defines TM contents. 0:Sensor data,1:Dump/fixed
TOF	10	E	Direct event time-of-flight pulse height
W	1	S	If 1, RAM reloaded from ROM due to detected fault.

#### Data Types:

R: 8 bit compressed counting rates. 4 bit exponent.

S: Status bits, bytes, words.

A: Analog bytes convertible to engineering units.

E: Direct event data (pulse heights, mass groups, etc.)

#### 12.2.1 LOMICS DATA REDUCTION

The information in this section consists of a brief description of some of the parameters readout to telemetry in LOMICS mode.

A matrix of four sets of 32 m/q values by 3 look directions are stored in the 512 matrix elements available during the instrument cycle. There are also 4 pages of memory each containing 6 m/q values to be selected for energy analysis. The m/q values need not be discrete values but can instead cover ranges (or bands) of m/q. Normal mode results in a 32 point energy spectrum ( 40 eV/q - 40 kev/q) for each selected constituent every major frame. The spectral data for a given m/q value are not simultaneously acquired; the delta time between successive energy (e/q) values is .128 seconds. The e/q values are not monotonic. There are three commandable modes for e/q operation: normal, constant, and changing. There is no way of knowing which e/q mode has been selected by examining the telemetry discretes. The mode must be determined by looking at the DPUB telemetry value "ESA" which, through a calibration, can be converted to the e/q value. Operationally, the routine modes for e/q, defined pre-launch, were to be 'normal' and 'fixed'.

#### 12.2.2 HIT DATA REDUCTION

The information in this section consists of a brief description of some of the parameters readout to telemetry in HIT mode.

The 512 element matrix accumulates counts for 16 masses at 32 energies over the full instrument cycle. The nominal mass range is 1-60 and the nominal energy range is 100 keV/ion - 15 MeV/ion. Thus a 32 point energy spectrum for each of the 16 masses is acquired every 65.536 seconds. The counts for the 16 by 32 matrix were simultaneously accumulated over the previous instrument cycle (65.536 seconds). There are 7 pages of commandable choices with each page containing 12 matrix elements selected for analysis by the rate scalars. The HIT page selected is stored in DPUB value "R-PRG" which can assume values of 1 through 7. A full set of rate scalar data is acquired every 2 minor frames. The rate scalar data is simultaneously accumulated over the previous 2 minor frames. As with the MICS and LOMICS, the HIT pages are reprogrammable and only the page number selected is readout by telemetry.

#### 12.3 PARAMETER LIST

LOMICS and HIT share the same DPU. The instruments can be commanded into either mode. Data taking periods for each instrument are some integral multiple of 65.536s (16 major frames). The THDB has 4.096 second blocks of DPUB telemetry data starting on minor frame 0. In addition, words are included to indicate a telemetry dropout indicator within the major frame; and a CSM/ LASSI data flag.

**CRRES TELEMETRY FORMAT - DPU B**  
**LOMICS MODE (NORMAL MODE) - 14AUG86 (REV E)**

		WORD 0 (64,128,192)	WORD 1 (65,129,193)	WORD 2 (66,130,194)	WORD 3 (67,131,195)	WORD 4 (68,132,196)
FMT	FRAME					
0	0	SYNC = 101101010	FORMAT/2 CTR	1 M N T K W D SU	HID 0	HID 1
	1	HS 1 = A0	HS 2 = B1	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	3	LR 1	LR 2	LR 3	LR 4	LR 5
	4	HID 2	HID 3	HID 4	MATRIX 0	MATRIX 1
	5	HS 3 = C1	HS 4 = MUXB	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	7	LR 1	LR 2	LR 3	LR 4	LR 5
	0	HID 5	HID 6	HSK 0	HID 7	HID 8
	1	HS 5 = STARTS	HS 6 = STOP2	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	3	LR 1	LR 2	LR 3	LR 4	LR 5
	4	HID 9	HID 10	HID 11	MATRIX 2	MATRIX 3
	5	SENSOR	STATUS	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	7	LR 1	LR 2	LR 3	LR 4	LR 5
2	0	COMMAND	VERIFY	0 M N T F R-PRG	HID 0	HID 1
	1	HS 1 = A0	HS 2 = B1	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	3	LR 1	LR 2	LR 3	LR 4	LR 5
	4	HID 2	HID 3	HID 4	MATRIX 4	MATRIX 5
	5	HS 3 = C1	HS 4 = MUXB	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	7	LR 1	LR 2	LR 3	LR 4	LR 5
	0	HID 5	HID 6	HSK 1	HID 7	HID 8
	1	HS 5 = STARTS	HS 6 = STOP2	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	3	LR 1	LR 2	LR 3	LR 4	LR 5
	4	HID 9	HID 10	HID 11	MATRIX 6	MATRIX 7
	5	SENSOR	STATUS	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	7	LR 1	LR 2	LR 3	LR 4	LR 5
3	0	HID 5	HID 6	HSK 1	HID 7	HID 8
	1	HS 5 = STARTS	HS 6 = STOP2	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	3	LR 1	LR 2	LR 3	LR 4	LR 5
	4	HID 9	HID 10	HID 11	MATRIX 6	MATRIX 7
	5	SENSOR	STATUS	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	LR 0
	7	LR 1	LR 2	LR 3	LR 4	LR 5

This pattern then repeats for each succeeding second. DPU B also has a HIT Mode, a Memory Dump Mode, and a Fixed Telemetry Mode. The Memory Dump Mode and the Fixed Telemetry Modes are not included in the THDB.



**CRRES TELEMETRY FORMAT - DPU B**  
**HIT MODE (NORMAL MODE) - 14AUG86 (REV E)**

		WORD 0 (64,128,192)	WORD 1 (65,129,193)	WORD 2 (66,130,194)	WORD 3 (67,131,195)	WORD 4 (68,132,196)
FMTFRAME						
0	0	SYNC = 101101010	FORMAT/2 CTR	1 M N T K W D SU	HID 0	HID 1
	1	HS 1 = A0	HS 2 = B1	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 0
	3	HR 1	HR 2	TOF (10)	DE (5)	E (8)
	4	HID 2	HID 3	HID 4	MATRIX 0	MATRIX 1
	5	HS 3 = C1	HS 4 = MUXB	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 3
1	7	HR 4	HR 5	TOF (10)	DE (5)	E (8)
	0	HID 5	HID 6	MSK 0	HID 7	HID 8
	1	HS 5 = STARTS	HS 6 = STOP2	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 6
	3	HR 7	HR 8	TOF (10)	DE (5)	E (8)
	4	HID 9	HID 10	HID 11	MATRIX 2	MATRIX 3
	5	SENSOR	STATUS	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
2	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 9
	7	HR 10	HR 11	TOF (10)	DE (5)	E (8)
	0	COMMAND	VERIFY	0 0 0 0 F R-PRG	HID 0	HID 1
	1	HS 1 = A0	HS 2 = B1	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 0
	3	HR 1	HR 2	TOF (10)	DE (5)	E (8)
	4	HID 2	HID 3	HID 4	MATRIX 4	MATRIX 5
3	5	HS 3 = C1	HS 4 = MUXB	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 0
	7	HR 4	HR 5	TOF (10)	DE (5)	E (8)
	0	HID 5	HID 6	MSK 1	HID 7	HID 8
	1	HS 5 = STARTS	HS 6 = STOP2	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	2	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 6
	3	HR 7	HR 8	TOF (10)	DE (5)	E (8)
	4	HID 9	HID 10	HID 11	MATRIX 6	MATRIX 7
	5	SENSOR	STATUS	LS 1 = T1*(T2)	LS 2 = T2 *(T3)	LS 3 = STARTS
	6	LS 4 = STOP1S	LS 5 = STOP2S	LS 6 = STOP3S	ESA	HR 9
	7	HR 10	HR 11	TOF (10)	DE (5)	E(8)

This pattern then repeats for each succeeding second. DPU B also has a LOMICS Mode, a Memory Dump Mode, and a Fixed Telemetry Mode. The Memory Dump Mode and the Fixed Telemetry Modes are not included in the THDB.

### 12.3.1 LOMICS

1. In normal mode six constituents are selected for energy analysis; m/q values of 1,2,4,8,16, plus one additional commandable constituent. There are 8 pages of choices; each page holds the 6 selected constituents. A 32 point energy spectrum (nominally between 40 eV/q and 40 keV/q) is produced for each constituent every 4.096 seconds (major frame).
2. The matrix of 32 m/q value by 3 look directions is stored. Four sets of this 96 element matrix are stored in the 512 available matrix locations.
3. The ESA step data.
4. The DPUB discretes.

### 12.3.2 HIT

1. As with MICS and LOMICS, HIT has a 512 element matrix of 32 energies by 16 masses. In the 65.536 seconds, counts are accumulated in each matrix element. Thus, a 32 point differential flux spectrum is obtained for each of the 16 fixed masses every 16 major frames.
2. There are 7 pages of choices each of which identifies 12 matrix elements. The 12 matrix elements are sent through rate scalars and are readout every 0.256 seconds. As with MICS and LOMICS, the page number file is required to identify the matrix elements selected.

## 12.4 THDB RECORD STRUCTURES

The LOMICS/HIT THDB file consists of a header record followed by a series of data records. Information in the header record is in 32 bit integer form. The data records are time tagged to the start of the major frame and contain the full set of DPUB data.

### HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (7011123)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-164	Vacant (Zero fill)

## DATA RECORDS

Word Number	Description
1	UT (milliseconds) at start of the major frame
2-6	DPUB data from minor frame 0
7-11	DPUB data from minor frame 1
.	.
.	.
.	.
157-161	DPUB data from minor frame 31
162	Byte 4 (MS BYTE):TLM mode indicator Bit 0 (LSB) = Telemetry indicator. Value is 0 when spacecraft TLM is in GTO mode. Value are set to 1 when a data gap follows due to a switch to either CSM or LASSII modes.
	Byte 3:Dropout indicator Bit 0 = 1 if there is 1's fill due to telemetry dropout anywhere in this record.
	Bytes 2 and 1 are vacant.
163-164	Vacant

## 13.0 AFGL-701-13-1 FLUXGATE MAGNETOMETER

### 13.1 INSTRUMENT DESCRIPTION

The purpose of this experiment is to measure the ambient geomagnetic field and low frequency variations in that field from d.c. to 8 Hz. This measurement is used:

- (1) together with the look angles of the particle experiments to obtain pitch angles of the measured particles;
- (2) as a diagnostic of global geomagnetic disturbances;
- (3) as a diagnostic of very low frequency waves in the ambient environment;
- (4) to provide plasma gyrofrequencies;
- (5) to measure  $v \times B$  electric fields; and
- (6) to provide a secondary source of spacecraft attitude information.

A Schonstedt Instrument Company triaxial fluxgate magnetometer measures the Earth's field 16 times per second in the range +45,000 nT. The signal from each sensor is sent to the Langmuir Probe electronics where it is filtered with a 8 Hz lowpass cutoff to prevent aliasing, and sampled by a 12 bit A/D converter in the range +45,000 nT and +900 nT to provide low and high sensitivity, respectively. For each sample from each axis, a microprocessor is used to determine whether to enter the high or low sensitivity value into the telemetry stream. Whenever the field strength along an axis is in the high sensitivity range, that value is entered into the telemetry stream with an

appropriate range indicator bit, otherwise the low sensitivity signal is sent. Furthermore, once per second the field strength at low sensitivity from all axes are included in the data stream. More than 70% of the time in the CRRES orbit is in field strengths where all three magnetometer axes are sending data in the high sensitivity range. The magnetometer data can also be sampled in a burst mode as described in the Langmuir probe instrument description. Additionally the fluxgate signal is lowpass filtered with a 20 Hz cutoff and provided to the spacecraft in analog form in two different ranges, +45,000 nT and +900 nT.

The three axes of the magnetometer are mutually orthogonal to approximately 0.08 degree. The sensors are mounted on a rigid, 6.1 m long Astromast boom and are far enough away from the spacecraft body so that the vehicle-generated magnetic field will have a strength less than a few nT at the sensor locations. The analog electronics to operate the sensors are mounted inside of the spacecraft with a link to the Langmuir probe electronics which will provide voltage regulation and telemetry formatting.

On command, the signal from one axis of the magnetometer can be amplified six times to provide better amplitude resolution at low field strengths near apogee.

### 13.2 REDUCTION PROCEDURES

The triaxial fluxgate science magnetometer measures the ambient field in the range  $\pm 45,000$  nT. The x, y, z, sensors are orthogonal, and are aligned such that the x sensor is along the spacecraft -x axis, with the y and z sensors close to the spacecraft -z, -y axes respectively (rotated  $-2.5^\circ$  about the spacecraft x axis). The output from these sensors is read out as 12 bit words at 16 times per second (actually 1.024 seconds based on a 16 kbps telemetry rate). A decision is made on the spacecraft to determine independently for each sensor whether to enter sampled data into the telemetry from the low gain ( $\pm 45,000$  nT) range or from the high gain ( $\pm 900$  nT) range. By default, the low gain data is used unless the signal strength is less than  $1/52$  of full scale, in which case the high gain data is entered into the telemetry. The  $1/52$  criterion can be changed by command to sample the high gain data whenever the signal is approximately in the range  $\pm 900$  nT. Additionally, low gain data is always sent twice per second. An extra times 6 amplification can also be in effect for the y sensor, at the discretion of the principal investigator.

Some experimenters in the GTO phase of the CRRES mission require knowledge of the magnetic field components at the minor frame rate. This requirement is met by providing on the agency tape, the telemetered 12 bit data corresponding to the x, y, and z sensor outputs. The twice per second low gain data accompanies every alternate sample of the 16 times per second data. Sensor

data is thus available at eight times per second, with low gain range readings always there for times concurrent with the first and fifth samples. Information for each sensor is provided in 16 bit format on the agency tape and, along with the 12 data bits on each frame, identifies whether the low or high gain range, and 6x amplification (for y) are in effect for that sample:

VALUE:	0	0	(6x)	(gain)	(telemetered 12-bit count word)											
BIT:	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	MSB															LSB

for bit 14, 1=6x; for bit 13, 1=HI gain

These data are converted to geophysical units using calibration data (gain & offset) provided by the magnetometer experimenter. A different gain and offset apply for each sensor in each gain state. Calibration data, based on ground based testing, is provided to each agency prior to launch, and is updated by the experimenter as required during the mission based on his ongoing review of the magnetometer data from every orbit. A memo listing recommended gain and offset factors applicable to each orbit is distributed periodically.

In addition to the science magnetometer outputs discussed above, which use the Langmuir Probe Instrument [AFGL701-14] for digital signal processing, analog magnetic field outputs from the science magnetometer are sent directly to the spacecraft in two ranges (+/- 1000nT and +/-45000nT). These analog signals are digitized by the spacecraft using 8 bits and are included on the agency tape magnetic field file along with a temperature monitor and bilevels which may be useful in calibrating the data. The high gain values are readout four times per major frame; the low gain data occurs once per major frame. Calibrations for the analog data are provided.

The high and low gain data from the spacecraft attitude magnetometers are also included on the magnetic field file in 8 bit telemetry form. This magnetometer is not located on the Astromast boom and is not the responsibility of the science magnetometer experimenter. All readouts occur at a rate of 4 points per major frame. This data provides magnetic field measurements during those periods when the spacecraft is being operated in LASSI telemetry mode (the Fluxgate Magnetometer system is not operated in LASSI mode). A flag bit is set in the file whenever the spacecraft telemetry is in LASSI mode.

### 13.3 PARAMETER LIST

The magnetic field file contains the millisecond time word, the 12 bit telemetered digital data corresponding to the x, y, z science magnetometer sensor outputs, the analog science magnetometer data, a temperature monitor, two 8 bit telemetry words which contain bilevels, and the analog values from the spacecraft attitude magnetometers. The 12 bit digital data is in

2's complement form, with a range of  $\pm 2047$ . Time is contained in a 32 bit word. The 12 bit digital values are stored in 16 bit words which include designators identifying the sensor range. These variable gain outputs (BX, BY and BZ) are written onto the agency tape at a rate of 8 times per second. The low gain digital values (BXL, BYL and BZL) are at a rate of 2 points per second. The high gain analog data (BXA, BYA and BZA) is included at a rate of 4 points per major frame; the low gain analogs (BXAL, BYAL and BZAL) occur once per major frame. The temperature monitor (A241) and bilevel words (B1, B2 and B30) occur once per major frame. The magnetometer analogs, temperature monitor and bilevels are stored in their 8 bit telemetry form. The spacecraft (X,Y,Z) attitude magnetometers for both high gain (XSCH,YSCH,ZSCH) and low gain (XSCL,YSCL,ZSCL) are included in 8 bit analog form at their full rate of 4 points per major frame. A flag bit is set to 1 whenever the spacecraft telemetry is in LASSI mode. Each record contains 16 master frames of data (approximately 65.536 seconds).

Telemetry dropout is 1's filled unless a full master frame is missing.

#### 13.4 THDB DATA RECORD STRUCTURE

The THDB files for the magnetometer consist of a header record followed by a series of data records. The header record is in 32 bit positive integer form. For the data records, all words are 32 bits; in the bit numbering sequence, bit 32 is the MSB of the 32 bit word; bit 1 is the LSB.

##### HEADER RECORD (All words 32 bit integers):

Word Number	Description
1	Experiment ID (701131)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-1200	Vacant (Zero fill)

##### DATA RECORDS:

Word	Bits	Description
1	32- 1	UT (milliseconds) at beginning of master frame
2	32-17	BXL(1)
	16- 1	BYL(1)
3	32-17	BZL(1)
	16- 1	BX(1)
4	32-17	BY(1)
	16- 1	BZ(1)
5	32-17	BX(2)

	16- 1	BY(2)
6	32-17	BZ(2)
	16- 1	BX(3)
.	.	.
.	.	.
.	.	.
9	32-17	BZ(4)
	16- 1	BXL(2)
10	32-17	BYL(2)
	16- 1	BZL(2)
11	32-17	BX(5)
	16- 1	BY(5)
.	.	.
.	.	.
.	.	.
16	32-17	BY(8)
	16- 1	BZ(8)
17- 32	Repeat order of words 1-16 for next second	
33- 48	Repeat order of words 1-16 for next second	
49- 64	Repeat order of words 1-16 for next second	
65	32-25	BXAL(1)
	24-17	BYAL(1)
	16- 9	BZAL(1)
	8- 1	BXA(1)
66	32-25	BYA(1)
	24-17	BZA(1)
	16- 9	BXA(2)
	8- 1	BYA(2)
67	32-25	BZA(2)
	24-17	BXA(3)
	16- 9	BYA(3)
	8- 1	BZA(3)
68	32-25	BXA(4)
	24-17	BYA(4)
	16- 9	BZA(4)
	8- 1	A241 (Temperature 1B monitor)
69	32-25	B1
	24-17	B2
	16- 9	B30
	8- 1	Telemetry flag (0=GTO mode, 1=LASSI mode)
70	32-25	XSCH(1)
	24-17	XSCH(2)
	16- 9	XSCH(3)
	8- 1	XSCH(4)
71	32-25	YSCH(1)
	24-17	YSCH(2)
	16- 9	YSCH(3)
	8- 1	YSCH(4)
72	32-25	ZSCH(1)
	24-17	ZSCH(2)
	16- 9	ZSCH(3)
	8- 1	ZSCH(4)
73	32-25	XSCL(1)
	24-17	XSCL(2)

	16- 9	XSCL(3)	
	8- 1	XSCL(4)	
74	32-25	YSCL(1)	
	24-17	YSCL(2)	
	16- 9	YSCL(3)	
	8- 1	YSCL(4)	
75	32-25	ZSCL(1)	
	24-17	ZSCL(2)	
	16- 9	ZSCL(3)	
	8- 1	ZSCL(4)	
76- 150	Repeat order of words 1-75 for 2nd master frame		
151- 225	Repeat order of words 1-75 for 3rd master frame		
.	.	.	.
.	.	.	.
1126-1200	Repeat order of words 1-75 for 16th master frame		

#### 14.0 AFGL-701-13-2 SEARCH COIL MAGNETOMETER AFGL-701-15 PASSIVE PLASMA SOUNDER

##### 14.1 INSTRUMENT DESCRIPTIONS

The purpose of the University of Iowa Passive Plasma Sounder (AFGL 701-15) and Search Coil Magnetometer (AFGL 701-13-2) Experiments, collectively known as the Plasma Wave Experiment on the SPACERAD GTO portion of CRRES, is to measure the plasma wave environment in the Earth's radiation belts. Emphasis is on high frequency and time resolution, high sensitivities (low noise levels), a large dynamic range, and sufficient frequency response to cover all the characteristic frequencies of the plasma that are of interest. The dynamic range for all of the receivers is about 100 dB (a factor of 105 in amplitude) beginning at the respective receiver's noise level. Past plasma wave measurements in the radiation belts show that this range adequately covers the expected range of plasma wave amplitudes detected by the electric and magnetic sensors. With a 100 meter tip-to-tip antenna, this range allows one to measure from the weak levels expected for the continuum radiation and  $(n + 1/2)$  fg emissions (fg is the electron gyro-frequency) outside the plasmasphere to the intense levels produced by upper hybrid resonance noise and ground transmitters observed inside the plasmasphere.

The Plasma Wave Experiment measures the electromagnetic and/or electrostatic fields detected by three sensors:

- (1) a 100-meter tip-to-tip extendible fine wire long electric dipole,
- (2) a search coil magnetometer mounted at the end of a 6-meter boom, and



- (3) a 100-meter tip-to-tip spherical double probe electric antenna. The first two sensors are the primary sensors for the Plasma Wave Experiment, while the third sensor is the primary sensor for the Langmuir Probe Experiment.

Signals from the sensors, after buffering by appropriate preamplifiers and differential amplifiers, are routed via antenna selection switches to the Sweep Frequency Receiver and the Multichannel Spectrum Analyzer in the Plasma Wave Experiment and Langmuir Probe Experiment.

The Sweep Frequency Receiver covers the frequency range from 100 kHz to 400 kHz in four bands with 32 steps per band.

Band 1 (100 Hz to 810 Hz) is sampled one step per second or 32 seconds per sweep, Band 2 (810 Hz to 6.4 kHz) is sampled two steps per second or 16 seconds per sweep, and Band 3 (6.4 kHz to 51.7 kHz) and Band 4 (51.7 kHz to 400 kHz) are each sampled four steps per second or 8 seconds per sweep.

The Multichannel Spectrum Analyzer consists of 14 narrow band filters logarithmically spaced in frequency (4 filters per decade in frequency) from 5.6 Hz to 10 kHz followed by 14 logarithmic compressors each having a dynamic range of about 110 dB. The 14 0.0 to 5.10 Volt DC analog outputs are sampled simultaneously 8 times per second to produce high time resolution spectra.

These instruments operate in GTO and CSM telemetry modes only. In CSM mode, however, not all of the telemetry words are present.

#### 14.2 REDUCTION PROCEDURES

Data from the Searchcoil Magnetometer (B), the Passive Plasma Sounder (E) and the Langmuir Probe (L) can be routed to either the Spectrum Analyzer (SA) or the Swept Frequency Receiver (SFR) for analysis.

The Swept Frequency Receiver (SFR) provides high frequency-resolution spectrum measurements from 100 Hz to 400 kHz in 128 channels (4 bands of 32 channels each). The telemetry designations for bands 1 through 4 are A260, A261, A262 and A263 respectively.

The telemetry locations for designations A260 through A263 is as follows:

Designation	Subcom	Subframes
A260	19	5, 13, 21, 29
A261	19	3, 7, 11, 15, ..., 31
A262	19	0, 2, 4, 6, ..., 30
A263	18	0, 2, 4, 6, ..., 30 .

The summary of the SFR telemetry is reflected in the table below:

Band Number	TLM Desig.	Seconds per spectra	Frequency Range (kHz)
1	A260	32	.108 - .799
2	A261	16	.836 - 6.23
3	A262	8	6.69 - 49.9
4	A263	8	53.5 - 399.

The time tag associated with each spectrum is in the analog sense (i.e. the spectral points are not simultaneously sampled). The time associated with each point in the spectrum is a function of the relative position of the corresponding analog word within the telemetry stream.

For the spectrum analyzer (SA), a 14 point frequency spectrum is readout every minor telemetry frame (0.128 sec). The minor frame word designations for the SA data are A246 through A259. These designations are located on minor frame words 138, 139, 142, 143, 170, 171, 174, 175, 202, 203, 206, 207, 234, and 235. The frequency range for the SA data is 5.6Hz to 10kHz. As with the SFR, the spectral points are not simultaneously taken; the time delta between points is a function of the relative position of the analog words within the telemetry stream.

The table of channel number, and approximate center frequency and effective noise bandwidth for the Spectrum Analyzer is given below:

Telem. Desig.	Channel No.	Center Freq.	Effective Noise Bandwidth
A246	01	5.6 Hz	1.12 Hz
A247	02	10.0 Hz	2.00 Hz
A248	03	17.8 Hz	3.56 Hz
A249	04	31.1 Hz	6.22 Hz
A250	05	56.2 Hz	11.2 Hz
A251	06	100. Hz	20.0 Hz
A252	07	178. Hz	35.6 Hz
A253	08	311. Hz	62.2 Hz
A254	09	562. Hz	112. Hz
A255	10	1.00 kHz	200. Hz
A256	11	1.78 kHz	356. Hz
A257	12	3.11 kHz	6.22 Hz
A258	13	5.62 kHz	560. Hz
A259	14	10.0 kHz	1.00 kHz

No SA data for telemetry designations A246, A250, A254, and A258 is received when the spacecraft telemetry is in CSM mode.

There are a total of 16 possible modes. The mode determination and sync (beginning of a cycle) are obtained from information contained on designation S37 which is located on sub frames 1, 9,

17 and 25 of subcom 19. The values which are readout in each 8 minor frame block are valid for that full second of data.

For both the SFR and SA, cycle modes can be commanded. The SFR cycle mode ("CYCLE 1") works on a 32.768 second cycle for each sensor. The order of the cycling is passive plasma sounder - search coil magnetometer - passive plasma sounder - Langmuir probe (E-B-E-L). The SA cycle ("CYCLE"2) operates on a major frame cycle basis with the instruments being cycled in the following order: search coil magnetometer - passive plasma sounder - search coil magnetometer - Langmuir probe (B-E-B-L). There are a total of 16 possible modes. The mode determination and sync (beginning of a cycle) frame are determined by use of designation S37. The table identifying information in the digital status word is given below:

Status Word Bits									Interpretation
Bits	0	1	2	3	4	5	6	7	
	0	0	0	x	x	x	x	x	SA Sensor=B, LOCK
	0	1	0	x	x	x	x	x	SA Sensor=Lang, LOCK
	1	0	0	x	x	x	x	x	SA Sensor=E, LOCK
	1	1	0	x	x	x	x	x	Not Valid
	0	0	1	x	x	x	x	x	SA CYCLE2, Sensor=B
	0	1	1	x	x	x	x	x	SA CYCLE2, Sensor=B
	1	0	1	x	x	x	x	x	SA CYCLE2, Sensor=E
	1	1	1	x	x	x	x	x	SA CYCLE2, Sensor=Lang
	x	x	x	0	0	0	x	x	SFR Sensor=E, LOCK
	x	x	x	0	1	0	x	x	SFR Sensor=LANG, LOCK
	x	x	x	1	0	0	x	x	SFR Sensor=B, LOCK
	x	x	x	0	0	1	x	x	SFR CYCLE1, Sensor=E
	x	x	x	0	1	1	x	x	SFR CYCLE1, Sensor=E
	x	x	x	1	0	1	x	x	SFR CYCLE1, Sensor=B
	x	x	x	1	1	1	x	x	SFR CYCLE1, Sensor=Lang
	x	x	x	x	x	x	0/1	x	SYN3 Lowest Freq Logic line
	x	x	x	x	x	x	x	0/1	"OR" of Top 4 Bits in SYN 1

In the table above, bit 0 is the most significant bit of S37. An x indicates that the a bit can be ignored. Bit 6 has a value of '0' for the lowest 16 channels of the low frequency SFR data; the value is '1' for the highest 16 channels. This value thus changes from '1' to '0' (on frame 1 of a major frame) to indicate the beginning of a 32 second instrument cycle. On initial turn-on, the instrument may not be synced to the spacecraft clock, but sync should occur within the first 32 seconds. Although S37 is on frame 1 (MOD 8), it's value should change from '1' to '0' only on subframe 1 of a major frame and the bit configuration is valid for the entire major frame.

Bits '0' through '2' uniquely define the SA status (including the measurement being read out in CYCLE2 mode). Similarly, bits '3' through '5' uniquely define the SFR status.

The conversion of the SFR and SA data from telemetry counts to science units involves the use of formulas and look up tables.

For the Swept Frequency Receiver, the calibration procedure is as follows:

For the E and L data,

$$\text{Spectral Density } (v^2 / m^2 / \text{Hz}) = [\text{COUNTS}(i,j) * M(i,j) * G(k,l) / \text{EAL}]^2 / \text{EB}$$

For B,

$$\text{Spectral Density } (nT^2 / \text{Hz}) = [\text{COUNTS}(i,j) * M(i,j) * G(k,l)]^2 / \text{EB}$$

where COUNTS(i,j) represents the PCM counts for the four bands (i) and the 256 possible values of the 8 bit readouts (j); M(i,j) is a 4 X 256 matrix to convert the PCM counts to voltage; G(k,l) is a 3 X 128 table of relative gain versus frequency factors for the 3 antennas and the 128 channels; EAL is the effective antenna length; and EB is the effective band width.

The calibration procedure for the Spectrum Analyzer is similar to that of the SFR.

For E and L data, the calibration equation is:

$$\text{Spectral Density } (v^2 / m^2 / \text{Hz}) = [\text{COUNTS}(i,j) * M(i,j) * G(k,l)]^2 / (\text{EAL})^2 / \text{EB}$$

where COUNTS(i,j) represents the 8 bit PCM counts for the 14 frequencies (i) and 256 (j) possible values of the 8 bit data; M(i,j) is a 14 X 256 matrix to convert COUNTS(i,j) from counts to voltage; G(k,l) is a 3 X 14 gain factor matrix for the 3 antennas and 14 frequencies; EAL is the effective antenna length; and EB is the effective bandwidth.

For the B data, the same equation may be used if EAL is set to 1.

The calibrated B units for the SA are  $[nT^2] / \text{Hz}$ .

The THDB data records are structured into 8 major frame blocks since this is the largest accumulation period for any of the data sets (SFA band 1 data). Thus, a record consists of one band 1 SFA spectrum; two SFA band 2 spectra; four SFA band 3 and band 4 spectra; 256 SA spectra; and the low voltage power supply (designation A264 - subcom 18 subframe 1), temperature (designation A265 - subcom 18 subframe 5) and command state (S37) from the first of the eight major frames comprising the 32.768 second block. All telemetry values are left in PCM counts. Code words are included every 8 SA spectra which indicates the instrument data source (passive plasma sounder, search coil magnetometer or Langmuir probe); similarly one code word per frame is included for the SFR to indicate data source. In addition, the Fast Digital Monitor (FDM) from the Berkeley microprocessor is included once per second (from subframe 0 [mod

8)). The FDM is located on minor frame word 135. The FDM is being included since the Langmuir probe (L) can be operated in Density/Temperature mode and E-Field mode and the FDM provides the indicator as to mode of the Langmuir. When the LSB of the FDM is 0, the spherical sensors are being operated in Langmuir probe mode; when the bit is 1, the spheres are in E-Field mode. An additional flag is included to indicate when the spacecraft telemetry mode is CSM since no SA data for telemetry designations A246, A250, A254, and A258 is received in that mode.

### 14.3 PARAMETER LIST

Magnetic field (B) spectra from the Search Coil Magnetometer, electric field (E) spectra from the Passive Plasma Sounder, and electric field spectra (L) from the Langmuir Probe are available through two processors: the Swept Frequency Receiver (SFR) and the Spectrum Analyzer (SA) at rates which have been commanded.

The SFR provides spectrum measurements at 128 frequencies. There are 4 bands of frequencies with 32 frequencies per band. The four bands readout the spectra at different rates.

Band No.	Frequency Range	Pts/Sec	Sec/Spectrum
1	104Hz-799Hz	1	32
2	836Hz-6.23kHz	2	16
3	6.69kHz-49.9kHz	4	8
4	53.5kHz-399kHz	4	8

The SA provides spectra at 14 frequencies (5.6Hz-10kHz) every 0.128 seconds.

Both the SFR and SA can be commanded to receive data from any of the three experiments. There are a total of 16 possible modes. These modes allow for routing data from any of the experiments to either receiver until commanded to change; or, cycling through the data from the instruments. For the SFR, CYCLE 1 mode outputs B-E-B-L at 32 seconds per sensor. For the SA, CYCLE 2 mode outputs B-E-B-L at 4 seconds per sensor.

The FDM from the Berkeley microprocessor is included at a rate of once per second in order to provide the indicator of Langmuir Probe mode. A CSM telemetry mode flag is also included once per major frame since, in that mode, four of the SA telemetry words are not present and there is no FDM data from the Berkeley microprocessor

### 14.4 THDB DATA RECORD STRUCTURE

The THDB files for this data consist of a header record followed by a series of data records. The header record is in 32 bit positive integer form. There is one data record every 8 major frames (32.768 sec). There is a 14 point SA spectrum every minor

frame. A code word precedes each set of 8 spectra to indicate the data type (1=passive plasma sounder, 2= Search coil magnetometer, 3= Langmuir probe). For the SFR, a code word precedes the data which indicates data type and whether the data type changed within the 8 major frames. Code word values are: 1 = passive plasma sounder, 2 = search coil magnetometer, 3 = Langmuir, 4 = data began as passive plasma sounder but did not end as passive plasma sounder, 5 = data began but did not end as search coil, 6 = data began as Langmuir but did not end as Langmuir. Spectral points occurring after the state change are 1 filled. Spectral points missing due to telemetry dropout are '1' filled. All spectra points are arranged from lowest to highest frequency. Each record has a total of 256 SA spectra: 1 band 1 SFR 32 point spectrum; 2 band 2 SFR 32 point spectra; 4 band 3 SFR 32 point spectra; and 4 band 4 SFR 32 point spectra. All telemetry words are in PCM counts (8 bits).

#### HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (701132)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-1032	Vacant (Zero fill)

#### DATA RECORDS:

Word No.	Description
1	UT (milliseconds)
2	Code word for next 8 SA spectra
3	SA points 1 thru 4 (4 8-bit bytes)
4	" " 5 8
5	" " 9 12
6	" " 13,14 and 1,2 from next spectrum
7	" " 3 thru 6
.	.
.	.
.	.
30	" " 11 thru 14
31-59	Repeat order of words 2-30 for next 8 spectra
60-88	Repeat order of words 2-30 for next 8 spectra
.	.
.	.
.	.
901-929	" " " " " " last 8 spectra
930	vacant
931	SFR code word
932-939	32 point band 1 spectrum
940-947	" " band 2 spectrum
948-955	" " band 2 spectrum

956-987	Four 32 point band 3 spectra
988-1019	Four 32 point band 4 spectra
1020	LVPS,temp,command state and a vacant byte (from first major frame)
1021-1028	32 values of the Berkeley FDM taken once per second (32 bytes)
1029-1030	Telemetry mode indicator once per major frame; 0 = GTO, 1= LASSI (and hence a data gap follows); 2 = CSM (and hence some IOWA words are invalid). (8 bytes)
1031	Dropout flag (value=1 if dropout in 8 major frames)
1032	Vacant

## 15.0 AFGL-701-14 LANGMUIR PROBE

### 15.1 INSTRUMENT DESCRIPTION

The Langmuir probe instrument for CRRES is designed to measure variations in cold electron temperature and density and electric fields which are crucial to the understanding of the wave modes and instabilities responsible for wave-particle interactions. Such interactions are responsible for pitch angle scattering of radiation belt protons and electrons into the atmosphere. During strong geomagnetic substorms, CRRES may observe processes characteristic of auroral magnetic field lines including solitary waves, double layers, and other plasma structures with electric fields parallel to the magnetic field.

In addition, the ability of the instrument to measure quasistatic DC electric fields at and within the geosynchronous orbit allows a detailed study of electric fields responsible for the earthward convection of particles from the plasma sheet, and the radial diffusion and energization of radiation belt particles to energies up to 1 MeV.

Advances in the technology of high density RAM memory have allowed 192 kilobytes of burst memory.

The CRRES Langmuir probe instrument consists of two pairs of orthogonal booms with tip-to-tip separations of 100 meters in the spin plane of the satellite. At the tips of opposing booms are conducting sensors. For one set of booms, these sensors are spheres; for the other set, they are cylindrical antennas. The cylindrical antennas are shared by the Passive Plasma Sounder and the Langmuir Probe Instrument. The CRRES Langmuir Probe instrument has two different operating modes which are controlled by an on-board microprocessor. When the instrument is operated in the Langmuir Probe mode, the spherical sensors are biased at fixed potentials relative to the plasma and the current collected by the spheres is measured. These data provide information on

cold electron temperature and density. In the electric field mode, the sensors are current-biased and measure electric fields by determining the potential difference between opposing sensors.

**Current Biasing.** The value of the bias current to the sensors can be adjusted between +.36 microamperes and -.36 microamperes in 256 linear steps. The bias current can be set either by ground command, or set to an optimum value determined by the digital control circuitry through on-board microprocessor analysis of bias sweeps, or set to a current that varies sinusoidally at the spin frequency.

**Langmuir Probe Mode.** During the Langmuir probe mode of operation, the spheres are biased at fixed voltages and their collected currents are measured. This mode is intended to measure the temperature and density of electrons with energies on the order of a few electron volts. Sphere currents are digitized by both the telemetry and burst electronics. During this mode of operation, voltage sweeps are used in the place of current sweeps as described above.

Data from the Langmuir Probe is readout only when the spacecraft is being operated in GTO telemetry mode.

The main telemetry quantities read out by the microprocessor are listed below.

#### Langmuir Probe - Main Telemetry Quantities

- 1) Potential difference between spherical probe 1 and the spacecraft or current gathered from spherical probe 2 (low frequency)
- 2) Potential difference between spherical probes or current collected by sphere 1 (low frequency signal)
- 3) Potential difference between spherical probe 1 and spacecraft or the current gathered by sphere 1
- 4) Automatic Gain Control (AGC)
- 5) Potential difference between spherical probe 1 and spacecraft or the current gathered by sphere 1
- 6) Potential difference between Cylindrical Probes
- 7) Bandpass filter 1 (center frequency = 32 Hz)
- 8) Bandpass filter 2 (center frequency = 256 Hz)
- 9) Bandpass filter 3 (center frequency = 2046 Hz)
- 10) Search coil
- 11) Potential difference between spherical probe 1 and spacecraft
- 12) Potential difference between cylindrical probe 3 and spacecraft
- 13) Potential difference between cylindrical probe 4 and spacecraft
- 14) Fluxgate magnetometer x component
- 15) Fluxgate magnetometer y component
- 16) Fluxgate magnetometer z component



The quantities which can be read out of burst memory are listed below.

#### Langmuir Probe - Burst Telemetered Quantities

- 1) Voltage between spherical probe 2 and spacecraft or current collected from spherical probe 2
- 2) Potential difference between spherical probe 2 and spherical probe 1 or current collected by spherical probe 1
- 3) Signal from search coil magnetometer or potential between spherical probe 2 and spacecraft
- 4) Potential between spherical probe 2 and spacecraft
- 5) Potential difference between two cylindrical probes (high frequency)
- 6) Potential difference between cylindrical probe 3 and spacecraft
- 7) DC potential difference between the two cylindrical probes
- 8) Potential difference between spherical probe 1 and spherical probe 2 (high frequency)
- 9) Potential difference between probe 3 and the spacecraft
- 10) Fluxgate magnetometer x axis
- 11) Fluxgate magnetometer y axis
- 12) Fluxgate magnetometer z axis
- 13) Automatic Gain Control

#### 15.2 REDUCTION PROCEDURES

The University of California at Berkeley microprocessor is highly versatile and is capable of reading out data from several instruments at variable rates. Instrument operation is commandable and memory is programmable, thus yielding a wide variety of output parameters and data rates.

The prime sensor outputs are stored in the high rate channels (HX0 through HX15) or the low rate channels (LX0 through LX31). The data from the 16 high rate (HX) channels is readout every two minor frames; the 32 low rate (LX) data requires 8 minor frames for a complete set of readouts. Gain bits (high gain or low gain) are readout for each LX and HX value.

The Digital Subcom (DSC) is 128 words deep and requires 8 major frames for a full readout; thus 16 values are readout each major frame. The first of each group of the 16 words is a 'MAJOR FRAME COUNT' which, when taken modulo 8, uniquely identifies the remaining 15 words in the major frame.

In the list of DSC words which appear later in this chapter, it can be seen that the definition of the parameters contained in the LX and HX channels can be determined from information in MAJOR FRAME COUNT 0, 1 and 2 (modulo 8). The 6 least significant bits of these words are used to determine the parameter stored in

each of the LX and HX values; the most significant bit, when set to 1, indicates that the word is a candidate to receive BURST memory data, and that the normal value to be readout in that location is replaced by BURST data whenever BURST is being readout. The bit adjacent to the MSB (referred to as r), when set to 1, indicates that the LX or HX information in that word contains a ram quantity. Thus, for the purposes of the THDB, any required LX or HX parameters are extracted from the bit stream only if the r bit is 0. For LX or HX values which are candidates for BURST memory, the values are extracted only when BURST is not being readout. The code for determining the parameters stored in the LX and HX channels is given in section 15.2.1. For each parameter and gain, there is a GAIN (G) and OFFSET (O) required in order to convert the 12 bit (signed) data to volts, i.e.

$$V1(\text{volts}) = (V1(\text{PCM}) + O_i)/G_i, \text{ where } i = \text{low or high.}$$

A pre-launch estimate expected that burst memory would be active approximately 50% of the time over the period of a year. Approximately 50% of the LX and HX words would receive burst data when the pre-programmed default mode is active. Burst data can be readout in either of two modes. One mode requires about 42 minutes to playback; the other requires about 120 minutes.

Since there are a wide variety out possible outputs from the microprocessor, several separate THDB files are generated. The LX and HX data is in 12 bit signed (2's complement) form; the values range from -2048 to +2047. For the THDB, storage of LX or HX parameters is accomplished by placing the 12 bit signed value into 16 bit words. Since each LX and HX value has a gain bit associated with it, the gain bit is stored in bit 13 of the word.

#### 15.2.1 DIGITAL SUBCOM ADDRESSES FOR LX AND HX DATA

The information contained in the 12 bit LX and HX readouts is identified in the DSC. The 8 bit words in the DSC for the LX and HX values are of the form:

brmmmmmm

where:

b=1 enables Main or Burst Playbacks to replace this channel when needed,  
 r=1 indicates that RAM quantity #mmmmmm is to be sampled,  
 r=0 indicates that the MAIN Multiplexor quantity #mmmmmm is to be sampled, mmmmmm= ADDRESS.

ADDRESS	LOW GAIN	HIGH GAIN
x0	BZ	BZ
x1	BY	BY
x2	BX	BX
x3	V3	V3
x4	V2/RI2	V2/RI2
x5	V1/SC	V1/SC
x6	V1	V1
x7	AGC	AGC**
x8	V12/RI1	V12/RI1
x9	F3	F3
xA	F2	F2
xB	F1	F1
xC	V4	V4
xD	AGC*	AGC*
xE	V12/RI1*	V12/RI1*
xF	V34	V34

(\*) INDICATES UNFILTERED QUANTITIES

(\*\*) INDICATES 'GARBAGE' QUANTITY

SC is the SEARCHCOIL

V3 and V4 are the voltages at V3 and V4 (Cylinders), respectively.

V34 is V3 - V4 (Cylinders); V12 is V1 - V2 (Spheres in E-Field mode)

RI1 and RI2 are the currents readout at spheres 1 and 2 during Langmuir Probe Density/Temperature mode.

F3, F2, and F1 are the outputs from the 3 filters.

### 15.2.2 SPIN FIT RESULTS

Spin fit coefficients to the electric field data as measured by the cylinders can be computed for each spin. Spin fit coefficients were produced for the spheres whenever they are being operated in E\_Field mode.

The least square fit is performed to an equation of the form:

$$E([t-T_0]) = A(hi) + A(lo) + B * \cos(w[t-T_0]) + C * \sin(w[t-T_0])$$

$$w = 2\pi v$$

where T0 is the time at the start of the spin fit period, and v is the spin frequency.

The microprocessor performs each least square fit in approximately 500 milliseconds. The fitting procedure is iterative with RMS point rejection used. The four coefficients to the least square fit which are readout include the phase, amplitude, and offset. In addition, the standard deviation to the fit and number of points used in the fit are readout. The

computed values are stored in telemetry designation SFR (spin fit results). The SFR telemetry words are zero between readouts from either the spheres or cylinders. A total of 17 8-bit SFR words are required for a full set of spin fit results. The indicator that a new set of spin fit coefficients is being readout is a 'sync and sensor' flag word. The values of the 8 bits are '10100xx' where the most significant portion of the word serves as the sync and the 'xx' value indicates the data source (x=01 for the spheres and x=11 for the cylinders). The next 15 SFR 8 bit words represent 24 bit words for, in order, AHI, ALO, B, C, and SIGMA. The last 8 bit word represents the final number of points used in the fitting procedure.

Thus, the telemetry word sequence for the spin fit results is as follows:

101000xx	AHI[0]	AHI[1]	AHI[2]	ALO[0]
ALO[1]	ALO[2]	B[0]	B[1]	B[2]
C[0]	C[1]	C[2]	SIGMA[0]	SIGMA[1]
SIGMA[2]	N			

The spin fit coefficients are placed in the THDB by storing the 24 bit form into 32 bit words. The 24 bits represent a sign bit (1 = negative), a 7 bit exponent, and a 16 bit mantissa. The formula to be used in converting the sign, exponent (E), and mantissa (M) to a floating point number is as follows:

$$\text{REAL} = (\text{SIGN}) * [ 2^{(E - 64)} * [M / 32768.] ]$$

The spin fit results are always available from the cylinders; they are available from the spheres when they are being operated in E-Field mode.

The coefficients from each spin fit along with the RMS value and the number of points used in the fit are stored in the THDB.

In order to determine T0, the start time of the spin fit period, the 2 byte value 'SPIN PERIOD', located on DSC words 120 and 121 (least significant byte is in word 120) is required. In addition, a flag is included to indicate the antenna from which the data came. The procedure for time tagging the start of the spin fit interval is as follows:

- Time tag the spin fit results readouts to the minor frame on which the spin fit 'sync word' occurs.

- b. Convert the "SPIN PERIOD" telemetry to true spin period (16ms per pulse).
- c. Compensate for the (approximately) .455 seconds required to compute the spin fit results.
- d. Thus, the time tag formula is:

$$\text{TIME (start)} = \text{TIME (minor frame)} - \text{SPIN PERIOD} - .455.$$

Information from the DSC is included in this file. It consists of the bias values from the spheres (BIAS1 AND BIAS2), the bias values from the cylinders (BIAS3 and BIAS4), the two stub values (STUB1 and STUB2) and the two guard values (GUARD1 and GUARD2). The spin fit coefficients for the spheres and cylinders are independently readout. Thus, for a given set of spin fit coefficients, the DSC data is taken from the 'most recent' set of required values.

The required telemetry information for the DSC values and their associated DSC word numbers are as follows:

Value	DSC Word Number
BIAS1	65
BIAS2	66
BIAS3	67
BIAS4	68
STUB1	69
STUB2	70
GUARD1	71
GUARD2	72

### 15.2.3 BAND PASS, SPACECRAFT POTENTIAL AND E-FIELD DATA

The data from the spheres is fed through three separate bandpass filters (32Hz, 256Hz and 1024Hz). The data from the 3 filters is to be put into the THDB at 1Hz. The first appearance of F1, F2, and F3 within a 1 second interval is selected. The bandpass words are designated F1, F2, and F3; and their corresponding "addresses" on the DSC HX and LX location words are xB, xA, and x9. For any given pass, these words may or may not be present on the HX or LX outputs. They could also be replaced by burst data when burst is active.

The bandpass values are valid only when there is test/calibrate is not in progress and when there are no bias sweeps.

The Fi are converted to voltage using the linear expressions based on gain. These voltages can then be converted to units of uV/m/SQRT(Hz) by use of another linear expression.

The quantities needed for the determination of spacecraft potential are V1, V2, V3 and V4. These four quantities are included at 1Hz. The first appearance of V1, V2, V3, and V4 within a 1 second interval is selected. Note that these quantities may not be available on the HX or LX channels or may be replaced when burst is active.

The V1 and V2 are valid only when the spheres are in voltage mode and there is no test/calibrate or bias sweeps. The default program mode for the spheres is to alternate between electric field mode and density/temperature mode every 128 spins of the spacecraft. This default mode can be changed by uplink command.

After conversion to voltage, the conversion to vehicle potential is a linear function of the form:

$$VEHPOT = a * (V1(\text{volts}) + V2(\text{volts}))/2 + b.$$

The quantities needed for the determination of high time resolution E-Field measurements are V12 and V34. These are stored (along with gain bits) at a rate of 1Hz. The V12 data is valid only when the spheres are in E-Field (voltage) mode.

The relay status is needed in the conversion of the voltage values to vehicle potential. The relay status information is contained on the DSC. The values stored are from the 'most recent' readout. The relay status bits, and word locations are as follows:

DSC word 52 Status of relays 7-0 in bits 7-0, respectively  
DSC word 53 Status of relays 15-8 in bits 7-0, respectively  
DSC word 54 Status of relays 23-16 in bits 7-0 respectively.

After conversion of the telemetry data to volts (based on gain), the voltages are converted to E-Field (in mv/m) by formulas of the form:

$$EFIELD = \text{Volts} / L.$$

For the spheres, the relay status (relay 10) must be tested. If the status is off, set L = L1; if the status is on, set L = L2.

A summary of the DSC information required to determine LX and/or HX word locations and burst candidate status for this data base is:

ADDRESS	LOW GAIN	HIGH GAIN
x3	V3	V3
x4	V2/RI2	V2/RI2
x5	V1/SC	V1/SC
x6	V1	V1
x8	V12/RI1	V12/RI1
x9	F3	F3
xA	F2	F2

xB	F1	F1
xE	V12/RI1*	V12/RI1*
xF	V34	V34

The FDM (from subframe 0 (MOD8)) is included. The FDM is necessary in order to determine the mode of the sphere data (E-Field or Langmuir).

The Fast Digital Monitor (FDM) is readout on every other minor frame. The bit order for the FDM is as follows: 'P', 'T', 'CC', 'X', 'S', 'E', 'M' where:

P = PLAYBACK	(1=Burst Playback is in progress)
T = TEST/CALIBRATE	(1=Test/calibrated in progress)
CC = BURST CONDITION CODE:	00 = Off
	01 = Searching
	10 = Collecting
	11 = Wait (preparing to playback)
X = MAIN/BURST PLAYBACK	1 = main playback
	0 = burst playback
S = BIAS SWEEP IN PROGRESS	(1 = sweep in progress)
E = COMMAND COUNT ERROR	(1=Error)
M = VOLTAGE/CURRENT MODE	(1 = Current [Langmuir]; 0 = Voltage [E-Field])

Test calibrate mode was estimated, pre-launch, to be used approximately once a month (1 to 2 minutes).

Sphere and cylinder sweeps are alternated and are synched with vehicle spin cycle. Sweeps occur every few spins (approximately every 4 minutes) at a given sun angle. First, a sphere voltage-mode/current-sweep is performed then, a quarter spin later, a cylinder sweep is performed.

Temperature data (TEMP2) is stored in the THDB in the event it is needed in the conversion from PCM to voltage.

#### 15.2.4 LANGMUIR DATA FOR DENSITY AND TEMPERATURE

The information contained in this section is included to provide an overview of the telemetry data required for the computation of density and temperature from the spheres when they are operated in current mode.

The raw counts data necessary for the calculation of density and temperature along with all other pertinent data for the calculations is stored in a file. This permitted the post-launch refinement of algorithms necessary for the density/temperature determinations. The sphere data acquired during current mode

along with the FDM value representing instrument mode is included in this file. The typical number of points in a sweep is 128.

The telemetry values containing the 'current' outputs are RI1 and RI2. The 'good' RIi values for density and temperature occur whenever the FDM indicates that the spheres are in current mode (M=1); there is no bias sweep in progress (S=0); and there is no test/calibrate in progress (T=0). In BURST mode (P=1), the appropriate LX and HX values must be checked to see if they are receiving RIi data or are being overwritten with BURST data. A Langmuir sweep always starts at the beginning of a telemetry major frame. For all sweeps, the voltage value at the end of a sweep is repeated as the first voltage for the sweep in the opposite direction (e.g. the last voltage at the end of an up-sweep is repeated as the first point of the down-sweep which follows). The DSC information which uniquely identifies the voltage sweep data is SAWTOOTH OFFSET, SAWTOOTH DELTA, SAWTOOTH PERIOD, and SAWTOOTH DIVIDER. The offset and delta are converted to voltage by a linear equation. SAWTOOTH OFFSET (in volts) is the voltage at the low end of the voltage sweep. SAWTOOTH DELTA is the difference in voltage between voltage steps. SAWTOOTH PERIOD defines the number of points in a sweep. SAWTOOTH DIVIDER is the divider of 64Hz (the nominal rate). Note that the data rate for the HX data is 64Hz. If the sawtooth divider is 2, then the voltage changes equivalently every 2nd HX data point. The correlation between the HX and LX outputs is as follows: HX(0), HX(1), LX(0), HX(2), HX(3), LX(1).... The LX(0) data point is tagged in time virtually the same as HX(1) [data is sampled only 2 minor frame words later than HX(1)]. So, with respect to the Langmuir probe, the voltage associated with any particular current measurement is directly related to the HX(i) values which receive the "current" data. The voltage on the Langmuir at the start of every telemetry major frame is SAWTOOTH OFFSET. If, for instance, SAWTOOTH PERIOD is 2, then HX(0) is associated with SAWTOOTH OFFSET, and HX(2) (and LX(0)) are associated with SAWTOOTH OFFSET + SAWTOOTH DELTA (since the voltage changes every 2/64 Hz).

The voltages associated with the current data stored in HX (or LX) locations are computed according to this pattern. The RIi telemetry values are converted to voltage using the standard  $V = (\text{COUNTS} + O_i) / G_i$  formula where  $i$ =low gain or high gain. These voltages are then converted to current by a linear expression of the form  $I = a * V + b$ .

The temperature value TEMP2 is stored in the data base in the event that it is needed in the conversion of PCM counts to volts.



# **BERKELEY TELEMETRY:**

MINOR FRAME	WORD	6	7	10	11	14	15
0							
	0+	HX0		HX1	DSC0	MAG0	MAG1
	32+	HX2		HX3	MAG2	MAG3	MAG4
	64+	HX4		HX5	MAG5	MAG6	MAG7
	96+	HX6		HX7	MAG8	MAG9	MAG10
	128+	GAINS	FDM				
	160+	LX0	--				
	192+	LX1	LX2				
	224+	LX3	*				

\*=GAINS FOR LX0 TO LX 3

MINOR FRAME	WORD	6	7	10	11	14	15
1							
	0+	HX8		HX9	EXP	MAG11	MAG12
	32+	HX10		HX11	MAG13	MAG14	MAG15
	64+	HX12		HX13	MAG16	MAG17	MAG18
	96+	HX14		HX15	MAG19	MAG20	MAG21
	128+	GAINS	SFR				
	160+	LX4	--				
	192+	LX5	LX6				
	224+	LX7	*				

\*=GAINS FOR LX4 TO LX 7

MINOR FRAME	WORD	6	7	10	11	14	15
2							
	0+	HX0		HX1	DSC1	MAG22	MAG23
	32+	HX2		HX3	MAG24	MAG25	MAG26
	64+	HX4		HX5	MAG27	MAG28	MAG29
	96+	HX6		HX7	MAG30	MAG31	MAG32
	128+	GAINS	FDM				
	160+	LX8	--				
	192+	LX9	LX10				
	224+	LX11	*				

\*=GAINS FOR LX8 TO LX 11

MINOR FRAME	WORD	6	7	10	11	14	15
7							
	0+	HX8		HX9	EXP	MAG33	MAG34
	32+	HX10		HX11	MAG35	MAG36	MAG37
	64+	HX12		HX13	MAG38	MAG39	MAG40
	96+	HX14		HX15	MAG41	MAG42	MAG43
	128+	GAINS	SFR				
	160+	LX28	--				
	192+	LX29	LX30				
	224+	LX31	*				

\*=GAINS FOR LX28 TO LX 31

# SUMMARY OF DATA READ OUT BY THE BERKELEY MICROPROCESSOR:

HX DATA: 8 WD/MINOR FRAME (12 BITS PER WORD)  
LX DATA: 4 WD/MINOR FRAME (12 BITS PER WORD)  
GAINS (HX): 8 BITS/MINOR FRAME  
GAINS (LX): 4 BITS/MINOR FRAME  
MAGNETOMETER: 11 WORDS/MINOR FRAME  
FDM: 1 WORD EVERY 2 MINOR FRAMES  
SFR: 1 WORD EVERY 2 MINOR FRAMES  
DSC: 1 WORD EVERY 2 MINOR FRAMES  
EXP: 1 WORD EVERY 2 MINOR FRAMES

## DATA DESCRIPTIONS:

HX data consists of 16 words. So, a full set of readouts is obtained every 2 minor frames (.256 seconds).

LX data consists of 32 words. A full set of readouts is obtained every 8 minor frames (1.024 seconds).

SFR: New values are readout as they are computed

DSC: DIGITAL SUBCOM is 128 words deep. Since it is read out at a rate of one WORD every other minor frame, the full subcom is read out over 8 master frames. The DSC contains the definitions of the parameter stored in the HX and LX outputs.

EXP: This value is unused at this time.

## DIGITAL SUBCOM

MINOR FRAME	DSC WORD NO.	DESCRIPTION
0	0	MAJOR FRAME COUNT (MOD 8 = 0)
2	1	HX( 0)
4	2	HX( 1)
6	3	HX( 2)
8	4	HX( 3)
10	5	HX( 4)
12	6	HX( 5)
14	7	HX( 6)
16	8	HX( 7)
18	9	HX( 8)
20	10	HX( 9)
22	11	HX(10)
24	12	HX(11)
26	13	HX(12)
28	14	HX(13)
30	15	HX(14)
0	16	MAJOR FRAME COUNT (MOD 8 = 1)
2	17	HX(15)

4	18	LX( 0)
6	19	LX( 1)
8	20	LX( 2)
10	21	LX( 3)
12	22	LX( 4)
14	23	LX( 5)
16	24	LX( 6)
18	25	LX( 7)
20	26	LX( 8)
22	27	LX( 9)
24	28	LX(10)
26	29	LX(11)
28	30	LX(12)
30	31	LX(13)
0	32	MAJOR FRAME COUNT (MOD 8 = 2)
2	33	LX(14)
4	34	LX(15)
6	35	LX(16)
8	36	LX(17)
10	37	LX(18)
12	38	LX(19)
14	39	LX(20)
16	40	LX(21)
18	41	LX(22)
20	42	LX(23)
22	43	LX(24)
24	44	LX(25)
26	45	LX(26)
28	46	LX(27)
30	47	LX(28)
0	48	MAJOR FRAME COUNT (MOD 8 = 3)
2	49	LX(29)
4	50	LX(30)
6	51	LX(31)
8	52	RAMBASE POINTER (*)
10	53	
12	54	EXECUTIVE VERSION
14	55	MODE TIMING
16	56	MODE CHANGE ANGLE
18	57	EXECUTIVE SPARE 0
20	58	EXECUTIVE SPARE 1
22	59	EXECUTIVE SPARE 2
24	60	EXECUTIVE SPARE 3
26	61	EXECUTIVE SPARE 4
28	62	VTRIM 12
30	63	VTRIM 34
0	64	MAJOR FRAME COUNT (MOD 8 = 4)
2	65	BIAS 1 (SPHERE)
4	66	BIAS 2 (SPHERE)
6	67	BIAS 3 (CYLINDER)
8	68	BIAS 4 (CYLINDER)
10	69	STUB 1
12	70	STUB 2
14	71	GUARD 1

16	72	GUARD 2
18	73	FILTER 1
20	74	FILTER 2
22	75	FILTER 3
24	76	FILTER 4
26	77	FILTER 5
28	78	FILTER 6
30	79	FILTER 7
0	80	MAJOR FRAME COUNT (MOD 8 = 5)
2	81	FILTER MUX
4	82	RELAY STATUS 0
6	83	RELAY STATUS 1
8	84	RELAY STATUS 2
10	85	SPHERE SWEEP OPTIONS
12	86	SPHERE SWEEP ANGLE
14	87	SPHERE SWEEP ALGORITHM
16	88	SPHERE SWEEP ALTERNATE BIAS
18	89	SPHERE SWEEP RESULT
20	90	SPHERE SWEEP M AVERAGE
22	91	CYLINDER SWEEP OPTIONS
24	92	CYLINDER SWEEP ANGLE
26	93	CYLINDER SWEEP ALGORITHM
28	94	CYLINDER SWEEP ALTERNATE BIAS
30	95	CYLINDER SWEEP RESULT
0	96	MAJOR FRAME COUNT (MOD 8 = 6)
2	97	CYLINDER SWEEP M AVERAGE
4	98	SAWTOOTH OFFSET
6	99	SAWTOOTH DELTA
8	100	SAWTOOTH PERIOD (*)
10	101	SAWTOOTH DIVIDER
12	102	BURST MODE/FREQ STATUS
14	103	BURST TRIGGER MODE
16	104	BURST DELAY TIME 0
18	105	BURST DELAY TIME 1
20	106	DEPLOYMENT STATUS
22	107	BOOM MICROSWITCHES
24	108	URNS COUNT BOOM 1
26	109	URNS COUNT BOOM 2
28	110	URNS COUNT LIMIT
30	111	PLASMA MODE REGISTER
0	112	MAJOR FRAME COUNT (MOD 8 = 7)
2	113	32.7 SEC CLOCK
4	114	2.25 HOUR CLOCK
6	115	24 DAY CLOCK COUNT
8	116	GOOD COMMAND COUNT
10	117	BAD COMMAND COUNT
12	118	SUN ANGLE (*)
14	119	
16	120	SPIN PERIOD (*)
18	121	
20	122	BOOM LENGTH 1
22	123	BOOM LENGTH 2
24	124	TEMPERATURE 1
26	125	TEMPERATURE 2

28	126	TEMPERATURE 3
30	127	TEMPERATURE 4

(\*) Indicates a 2 byte value which is given with the low byte first.

#### Notes:

24 DAY CLOCK is the count of 24 days since reset.

2.25 HOUR CLOCK is the count of 2.25 hours since reset.

32.7 SEC CLOCK is the count of 32.7 seconds since reset.

SPIN PERIOD - A 16 bit value of the spin period as the number of 16ms counting periods between sun pulses.

SUN ANGLE - A 16 bit value of the angle between the sun sensor and the sun. The low 8 bits subdivide a spin in 256 equal parts of 1.41 degrees each. The upper byte is an overflow which shows that the sun sensor is not working (this occurs in shadow).

### 15.3 PARAMETER LIST

THDB parameter availability and data rates for the AFGL 701-14 are a function of instrument mode.

The parameters for the THDB are:

1. Least square fit coefficients to the electric field data as measured by the cylinders. The coefficients for the spheres are included whenever they are available. The data rate for each set of coefficients is once per spin.
2. Bandpass data.
3. Spacecraft potential.
4. High time resolution electric field data.
5. Density and temperature data.

### 15.4 THDB DATA RECORD STRUCTURE

There are two separate data bases generated for the Berkeley microprocessor: the Spin Fit Coefficient file; and the Bandpass, Spacecraft Potential and E-Field file.

#### 15.4.1 SPIN FIT COEFFICIENT FILE.

HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (701141)
2	Year
3	Day of Year

4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-12	Vacant (Zero fill)

#### DATA RECORDS:

Word Number	Description
1	UT (at start of minor frame containing the beginning of a new set of spin fit readouts)
2	Data type flag (0 = results from spheres; 1 = results from cylinders)
3	AHI (24 bits right adjusted in 32 bit word)
4	ALO (24 bits right adjusted in 32 bit word)
5	B (24 bits right adjusted in 32 bit word)
6	C (24 bits right adjusted in 32 bit word)
7	SIGMA (24 bits right adjusted in 32 bit word)
8	SPIN PERIOD (2 right adjusted bytes from the DSC with DSC word 120 as the least significant byte of the 32 bit word)
9	Byte 1: N (number of points remaining in the fit) Byte 2: BIAS1 (in PCM counts) Byte 3: BIAS2 " " Byte 4: BIAS3 " "
10	Byte 1: BIAS4 " " Byte 2: STUB1 " " Byte 3: STUB2 " " Byte 4: GUARD1 " "
11	Byte 1: GUARD2 " " Bytes2-4: Vacant
12	Bytes1-4: Vacant

**Note:** The spin fit coefficients are placed in the THDB by storing the 24 bit form into 32 bit words. The 24 bits represent a sign bit (1=negative), a 7 bit exponent, and a 16 bit mantissa. The formula to be used in converting the sign, exponent (E), and mantissa (M) to a floating point number is as follows:

$$\text{REAL} = (\text{SIGN}) * [ 2^{*(E - 64)} * [M / 32768.] ]$$

#### 15.4.2 BAND PASS, SPACECRAFT POTENTIAL, AND E-FIELD FILE.

This data base consists of a header record, an HX channel identification record, a LX channel identification record, and a series of data records. The LX/HX channel identification records consist of the first set of LX/HX identifiers in the DSC for this orbit. These values are likely to remain constant for an entire orbit since the channel assignments can be changed only by uplink command. The full DSC is included in the data records so that any changes can be identified.

# HEADER RECORD (All words 32 bit integers):

Word Number	Description
1	Experiment ID (701142)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-12	Vacant (Zero fill)

## HX CHANNEL IDENTIFICATION RECORD:

Word Number	Description
1	Byte 1: HX( 0) identifier
	Byte 2: HX( 1) identifier
	Byte 3: HX( 2) identifier
	Byte 4: HX( 3) identifier
2	Byte 1: HX( 4) identifier
	Byte 2: HX( 5) identifier
	Byte 3: HX( 6) identifier
	Byte 4: HX( 7) identifier
3	Byte 1: HX( 8) identifier
	Byte 2: HX( 9) identifier
	Byte 3: HX(10) identifier
	Byte 4: HX(11) identifier
4	Byte 1: HX(12) identifier
	Byte 2: HX(13) identifier
	Byte 3: HX(14) identifier
	Byte 4: HX(15) identifier
5-12	Vacant

## HX CHANNEL IDENTIFICATION RECORD:

Word Number	Description
1	Byte 1: LX( 0) identifier
	Byte 2: LX( 1) identifier
	Byte 3: LX( 2) identifier
	Byte 4: LX( 3) identifier
2	Byte 1: LX( 4) identifier
	Byte 2: LX( 5) identifier
	Byte 3: LX( 6) identifier
	Byte 4: LX( 7) identifier
3	Byte 1: LX( 8) identifier
	Byte 2: LX( 9) identifier
	Byte 3: LX(10) identifier
	Byte 4: LX(11) identifier
4	Byte 1: LX(12) identifier
	Byte 2: LX(13) identifier
	Byte 3: LX(14) identifier
	Byte 4: LX(15) identifier
5	Byte 1: LX(16) identifier

	Byte 2:	LX(17)	identifier
	Byte 3:	LX(18)	identifier
	Byte 4:	LX(19)	identifier
6	Byte 1:	LX(20)	identifier
	Byte 2:	LX(21)	identifier
	Byte 3:	LX(22)	identifier
	Byte 4:	LX(23)	identifier
7	Byte 1:	LX(24)	identifier
	Byte 2:	LX(25)	identifier
	Byte 3:	LX(26)	identifier
	Byte 4:	LX(27)	identifier
8	Byte 1:	LX(28)	identifier
	Byte 2:	LX(29)	identifier
	Byte 3:	LX(30)	identifier
	Byte 4:	LX(31)	identifier
9-12			Vacant

#### DATA RECORDS:

Word Number	Description
1	UT (at start of minor frame for this 1.024 second period (minor frame 0 (mod 8)))
2	Bits 31-16: V1
	Bits 15-0: V2
3	Bits 31-16: V3
	Bits 15-0: V4
4	Bits 31-16: V12
	Bits 15-0: V34
5	Bits 31-16: F1
	Bits 15-0: F2
6	Bits 31-16: F3
	Bits 15-0: Vacant
7	Byte 1: TEMP2 monitor
	Byte 2: DSC word 52
	Byte 3: DSC word 53
	Byte 4: DSC word 54
8	Byte 1: FDM (from minor frame 0 (mod8))
	Byte 2: Minor frame number at the start of this 1 second interval
	Byte 3: First DSC value in this time interval
	Byte 4: Second DSC value in this time interval
9	Byte 1: Third DSC value in this time interval
	Byte 2: Fourth DSC value in this time interval
	Byte 3: Dropout flag; ( value is 1 if there is telemetry dropout in this 1 second interval)
	Byte 4: CSM / LASSII flag; (value is 1 if a data gap follows this record due to



a switch to CSM or LASSII telemetry modes)

10-12      Vacant

**Notes:**

1. The 12 bit values are stored right-adjusted within the 16 bit locations. The decimal value of the 12 bit telemetry data ranges between -2048 and +2047. To obtain the proper value from these 12 bits, subtract 4096 if the value exceeds +2047. The 13th bit is the gain bit for the readout ( 0 = low gain, 1 = high gain). The 14th bit is set to 1 if the parameter is a candidate for over-write by burst memory readout. If this bit is 1 and the 'P' bit from the FDM is 1, the value is invalid.
2. The values of V1, V2, V3, V4, V12, V34, F1, F2, and F3 are 1's filled if they were not available on any of the LX or HX channels. These values should be considered to be invalid if the sensor is in test/calibrate mode (FDM 'T' bit equal to 1).
3. The V1, V2, and V12 values are invalid if the spheres are in current mode (FDM 'M' bit equal to 1) and may be invalid if a bias sweep is in progress (FDM 'S' bit equal 1).
4. The V3, V4, and V34 values may be invalid if a bias sweep is in progress.

**16.0 ONR-307-3-1,-2,-3 SPECTROMETER FOR ELECTRONS AND PROTONS (SEP)**

**16.1 INSTRUMENT DESCRIPTION**

The ONR-307-3 Spectrometer for Electrons and Protons (SEP) measures with fine pitch-angle resolution the flux of energetic electrons in the energy range of 20 to 5000 keV and the flux of energetic protons in the energy range 500 keV to 100 MeV. The instrument consists of three identical particle telescopes composed of surface-barrier silicon detectors with active anticoincidence shielding and narrow collimation (3 degrees FWHM). The energy spectra is measured with fine energy resolution.

The overall objective of the ONR-307-3 experiment is to obtain necessary data to construct predictive models, suitable for engineering purposes, of the energetic particle and plasma environment in those regions of space of primary interest to the Department of Defense satellite operations.

The specific objectives of this experiment are:

1. To measure the intensity, energy spectra, and pitch angle distribution of energetic electrons and as a function of time. These measurements characterize the dynamical behavior of the radiation belts.
2. To compute accurately the total omnidirectional flux at the satellite position.
3. To understand the physics of the sources, energization, transport, lifetimes, and losses of energetic particles in the earth's radiation belts.
4. To understand the details of wave-particle interactions (WPI), both natural and man-made, that are a principal loss mechanism for radiation belt particles. These WPI produce particle precipitation into the ionosphere that can disrupt radiowave communications of vital interest to the U.S. Navy.
5. To utilize this experimental data base to greatly improve the accuracy of the trapped radiation belt models and to characterize model particle precipitation.

Three spectrometers are stacked at various angles to the CRRES spin axis (80, 60 and 40 degrees). The instrument operates from a 768-word CMOS memory that is composed of 256 8-bit words which are individually addressable and loadable via a 16-bit serial-digital command. Twelve of these words (32-bit control register for each of the three sensors) completely define one operating mode of the instrument. A MODE is defined by specifying the logic conditions (coincidence/anticoincidence), gain, and energy thresholds required between the four detector elements (D, E, E', A) to uniquely establish a particle type and energy range for analysis. A choice of two amplifier gain settings for the D and E detectors is available. The lower and upper energy thresholds selected for analysis by the 12-channel pulse-height-analyzer (PHA) are determined to 8-bit and 6-bit resolution, respectively.

Typical modes that may be used during the CRRES mission are shown below:

SPECIES	MODE	ENERGY RANGE	CHANNEL WIDTH
ELECTRONS	ELEC1	20-300 keV	20 keV
	ELEC2	300-5000 keV	400 keV
PROTONS	PROT1	0.5-4.5 MeV	330 keV
	PROT2	4.5-20 MeV	1.25 MeV
	PROT3	20-45 MeV	2.0 MeV
	PROT4	45-100MeV	4.2 MeV

## 16.2 REDUCTION PROCEDURES

There are 3 sensors mounted at 80, 60, and 40 degrees to the spacecraft spin axis.

Each of the sensors:

- i) is independently commandable.
- ii) is capable of making electron measurements between 20-5000keV, or proton measurements between 0.5-100 MeV; actual energy ranges selected in both electron and proton mode are commandable.
- iii) provides differential flux spectra along with four integral flux measurements.

Telemetry for the 3 sensors is on designation S38 which appears 19 times per minor frame for the science data (in GTO telemetry mode, the minor frame words are 12, 17, 41, 44, 49, 76, 81, 108, 113, 124, 140, 145, 172, 177, 204, 209, 233, 236, and 241). The minor frame word numbers are different in LASSII telemetry mode but the word locations on the Agency Tape are the same as for GTO mode. There are 15 subcom words per major frame for status information (subcom 17, subframes 0 through 14).

A review of early post-launch data indicates that the spectra outputs in LASSII mode are inconsistent with expected values and the status bits do not relate to any of the sensor operating modes.

The 80 and 60 degree sensors produce 2 sets of 12 point spectra every .512 seconds; the 40 degree sensor produces one 12 point spectrum in the same .512 seconds. Each of the sensors has 4 integral flux channels.

The readout order within 4 minor frames is given below. The letters A, B and C represent the 80, 60, and 40 degree sensors, respectively. The numbers represent the energy channel numbers.

Word	Minor Frame			
	0	1	2	3
1	P2A	P2B	-----	
2	P4A	P4B		
3	P6A	P6B	REPEAT	
4	P8A	P8B		
5	P10A	P10B	ORDER	
6	P12A	P12B		
7	P1A	P1B	OF WORDS 1-14	
8	P3A	P3B		
9	P5A	P5B	FROM FRAMES	
10	P7A	P7B		
11	P9A	P9B	0 AND 1	
12	P11A	P11B		
13	DA	DB		
14	EA	EB		

15	AA	AB	EPA	EPB
16	P2C	P10C	P5C	DC
17	P4C	P12C	P7C	EC
18	P6C	P1C	P9C	AC
19	P8C	P3C	P11C	EPC .

The symbols D, E, A and EP (E prime) represent the integral flux channels.

The status information on the subcom contains bits to indicate:

1. Primary and secondary data format. The word order for the primary mode was defined above. In secondary mode, the data is circular shifted starting at the 9th readout for each sensor.
2. Cal on/off
3. Dwell time in a mode
4. Normal/backup mode. Backup mode is the hardwired mode which is used when the instrument is turned on.
5. PHA lower level and PHA upper level counts. These counts convert to voltage and then to energy and represent the upper and lower energy ranges for the present mode. It should be noted that the upper level counts value is only 6 bits and 2 'zero bits' should be added to the LSB end of the word to construct an 8 bit word. Once Emax and Emin are known, the energy range for each of the channels is obtained by computing delta energy (delE) as defined by:

$$\text{delE} = (\text{EMAX} - \text{EMIN}) / 12.$$

The lower energy value for each of the channels is then given by:

$$\text{Emin}(i) = \text{EMIN} + (i-1) * \text{delE}, i=1,12.$$

The central energy for each channel is simply

$$[\text{Emax}(i) + \text{Emin}(i)] / 2.$$

6. The sensors can be commanded to produce 11 point differential flux spectra with the 12th channel (highest energy channel) being used as an integral flux channel. This is noted in the subcom by the discrete "PHA SLOPE". If the value is "1", then the 12th channel is an integral channel. The value of EMAX in the subcom is always defined for 12 channels independent of whether the 12th channel is an integral channel.
7. The "D/E Lower Level" bits represent the lower threshold for either the D or E detector. One of the detectors goes to the PHA, the other is used for either coincidence or anti-coincidence (depending on the mode). This threshold applies to the one that is used for coincidence/anti-coincidence.

The subcom information for sensors A and B is obtained once per major frame. The information for sensor C requires 2 major frames for a full readout. There are 15 words per major frame.

The status word information and bit order is given below:

WORDS 0-11 ARE THE SAME ON ALL MAJOR FRAMES

WORD 0 (SENSOR A)

BITS DESCRIPTION

7 DATA FORMAT 0=PRIMARY, 1=SECONDARY  
6 1=CAL ON, 0=CAL OFF  
5-4 MODE DWELL TIME; 0=4S, 1=8S, 2=16S, 3=32S  
3 1=BACKUP MODE; 0=NORMAL  
2-0 MEMORY PAGE ID - IDENTIFIED MEMORY PAGE SELECTED

WORD 1 (SENSOR A)

BITS DESCRIPTION

7-5 MODE ID - IDENTIFIES PRESENT SENSOR A OPERATING MODE  
4 1=RUN, 0=MEMORY LOAD  
3 1=CAL NORMAL, 0=CAL PULSER DISABLED  
2 1=ANTI ON, 0=ANTI OFF  
1 1=MEMORY INVALID, 0=MEMORY NORMAL  
0 1=INVALID COMMAND; 0=NORMAL

WORD 2 (SENSOR A)

BITS DESCRIPTION

7 A-LOGIC MODE; 1=INHIBIT, 0=ANTI  
6 E PRIME - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
5 E - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
4 D - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
3 A - THRESHOLD; 1=HIGH, 0=LOW  
2 E PRIME - THRESHOLD; 1=HIGH, 0=LOW  
1 PHA SLOPE; 1=SINGLE, 0=DUAL  
0 AMPLIFIER GAIN; 1=HIGH, 0=LOW

WORD 3 (SENSOR A)

BITS DESCRIPTION

7-0 D/E LOWER LEVEL; REPRESENTED AS 2 DIGIT HEX EQUIVALENT

WORD 4 (SENSOR A)

BITS DESCRIPTION

7-0 PHA LOWER THRESHOLD; REPRESENTED AS 2 DIGIT HEX EQUIVALENT

WORD 5 (SENSOR A)

BITS DESCRIPTION

7-2 PHA UPPER THRESHOLD - REPRESENTED AS 2 DIGIT HEX EQUIVALENT  
1 SENSOR PHA ID; 1=D-SENSOR, 0=E-SENSOR  
0 PHA CONTROL; 1=CONTINUOUS ENABLE, 1=CONDITIONAL ENABLE

WORD 6 (SENSOR B)

BITS DESCRIPTION

7 DATA FORMAT 0=PRIMARY, 1=SECONDARY  
 6 1=CAL ON, 0=CAL OFF  
 5-4 MODE DWELL TIME; 0=4S, 1=8S, 2=16S, 3=32S  
 3 1=BACKUP MODE; 0=NORMAL  
 2-0 MEMORY PAGE ID - IDENTIFIED MEMORY PAGE SELECTED

WORD 7 (SENSOR B)

BITS DESCRIPTION

7-5 MODE ID - IDENTIFIES PRESENT SENSOR A OPERATING MODE  
 4 1=RUN, 0=MEMORY LOAD  
 3 1=CAL NORMAL, 0=CAL PULSER DISABLED  
 2 1=ANTI ON, 0=ANTI OFF  
 1 1=MEMORY INVALID, 0=MEMORY NORMAL  
 0 1=INVALID COMMAND; 0=NORMAL

WORD 8 (SENSOR B)

BITS DESCRIPTION

7 A-LOGIC MODE; 1=INHIBIT, 0=ANTI  
 6 E PRIME - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
 5 E - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
 4 D - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
 3 A - THRESHOLD; 1=HIGH, 0=LOW  
 2 E PRIME - THRESHOLD; 1=HIGH, 0=LOW  
 1 PHA SLOPE; 1=SINGLE, 0=DUAL  
 0 AMPLIFIER GAIN; 1=HIGH, 0=LOW

WORD 9 (SENSOR B)

BITS DESCRIPTION

7-0 D/E LOWER LEVEL; REPRESENTED AS 2 DIGIT HEX EQUIVALENT

WORD 10 (SENSOR B)

BITS DESCRIPTION

7-0 PHA LOWER THRESHOLD; REPRESENTED AS 2 DIGIT HEX EQUIVALENT

WORD 11 (SENSOR B)

BITS DESCRIPTION

7-2 PHA UPPER THRESHOLD - REPRESENTED AS 2 DIGIT HEX EQUIVALENT  
 1 SENSOR PHA ID; 1=D-SENSOR, 0=E-SENSOR  
 0 PHA CONTROL; 1=CONTINUOUS ENABLE, 1=CONDITIONAL ENABLE

MAJOR FRAMES 0, 2, 4, AND 6:

WORD 12 (SENSOR C)

BITS DESCRIPTION

7 DATA FORMAT 0=PRIMARY, 1=SECONDARY  
 6 1=CAL ON, 0=CAL OFF  
 5-4 MODE DWELL TIME; 0=8S, 1=16S, 2=32S, 3=64S  
 3 1=BACKUP MODE; 0=NORMAL  
 2-0 MEMORY PAGE ID - IDENTIFIED MEMORY PAGE SELECTED

WORD 13 (SENSOR C)

BITS DESCRIPTION

7-5      MODE ID - IDENTIFIES PRESENT SENSOR A OPERATING MODE  
 4        1=RUN, 0=MEMORY LOAD  
 3        1=CAL NORMAL, 0=CAL PULSER DISABLED  
 2        1=ANTI ON, 0=ANTI OFF  
 1        1=MEMORY INVALID, 0=MEMORY NORMAL  
 0        1=INVALID COMMAND; 0=NORMAL

WORD 14 (SENSOR C)

BITS      DESCRIPTION  
 7        A-LOGIC MODE; 1=INHIBIT, 0=ANTI  
 6        E PRIME - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
 5        E - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
 4        D - LOGIC MODE; 1=COINCIDENCE; 0=ANTI  
 3        A - THRESHOLD; 1-HIGH, 0=LOW  
 2        E PRIME - THRESHOLD; 1=HIGH, 0=LOW  
 1        PHA SLOPE; 1=SINGLE, 0=DUAL  
 0        AMPLIFIER GAIN; 1=HIGH, 0=LOW

MAJOR FRAMES 1, 3, 5, AND 7.

WORD 12 (SENSOR C)

BITS      DESCRIPTION  
 7-0      D/E LOWER LEVEL; REPRESENTED AS 2 DIGIT HEX EQUIVALENT

WORD 13 (SENSOR C)

BITS      DESCRIPTION  
 7-0      PHA LOWER THRESHOLD; REPRESENTED AS 2 DIGIT HEX EQUIVALENT

WORD 14 (SENSOR C)

BITS      DESCRIPTION  
 7-2      PHA UPPER THRESHOLD - REPRESENTED AS 2 DIGIT HEX EQUIVALENT  
 1        SENSOR PHA ID; 1=D-SENSOR, 0=E-SENSOR  
 0        PHA CONTROL; 1=CONTINUOUS ENABLE, 1=CONDITIONAL ENABLE

The 256 word memory holds 8 pages of modes for each detector. Each page defines 8 modes. A page is selected by uplink command and that page remains in effect until a command is sent to change the page. Once a page is selected, the instrument steps through the modes in a cyclic manner, i.e. 0, 1, 2, 3, 4, 5, 6, 7, 0, 1, 2, ..., dwelling in each mode for the prescribed amount of time. The pages are numbered 0 through 7. There is a calibration mode for each instrument. The calibration mode is always page 7. It should be noted that all three instruments can be in different modes at any given time.

During early on-orbit operations, the MODES and page definitions were as follows:

MODE	SEPA	SEPB	SEPC
ELECT1	42-324keV	42-336keV	41-313keV

	delE=23.5	delE=24.5keV	delE=22.7
ELEC2	.212-5.03MeV delE=402keV	.218-5.15MeV delE=410keV	.209-.08MeV delE=406keV
PROT1	.875-6.60MeV delE=478keV	.916-6.70MeV delE=482keV	.920-6.80MeV delE=490keV
PROT2	2.5-38.7MeV delE=3.01MeV	2.2-33.7MeV delE=2.62MeV	2.0-30.4MeV delE=2.37MeV
PROT3	35.8-80.2MeV delE=3.7MeV	31.2-69.9MeV delE=3.22MeV	28.2-63.1MeV delE=2.91MeV
PROT4	45-94MeV delE=4.08MeV	45-105MeV delE=5.00MeV	45-110MeV delE=5.42MeV
ALPHAS	6.8-24MeV delE=1.43MeV	6.90-24.3MeV delE=1.45MeV	7.00-24.6MeV delE=1.47MeV

The numbers defined above we the pre-launch values.

The early on-orbit PAGE definitions were as follows:

PAGE 0 :  
ELECT1  
ELECT2  
(pattern cycles)

PAGE 1:  
ELECT1  
ELECT2  
PROT1  
PROT2  
PROT3  
PROT4  
PROT4  
ALPHAS

PAGE 2:  
ELECT1  
ELECT1  
ELECT1  
ELECT2  
(pattern cycles)

PAGE 3:  
All ELECT2

PAGE 4:  
PROT1  
PROT1  
PROT1  
ELECT2



(pattern cycles)

PAGE 5:

PROT2

PROT2

PROT2

ELECT2

(pattern cycles)

PAGE6:

Current PHA Lower/Upper Counts

ELECT1 17-124

ELECT2 6-180

PROT1 10-64

PROT2 8-120

(pattern cycles)

PAGE 7:

Always CALIBRATION

There is a hardwired mode for each instrument. The instruments wake up in this mode whenever they are turned on; they also switch to this mode whenever commands are being sent to the instruments. This mode definition is ELECT2.

The 8 bit readouts on the minor frame words represent compressed counts. The Lockheed 8 bit decompression algorithm is used to decompress the 8 bit readouts into true counts. This algorithm is as follows:

$$\text{COUNTS} = M, E=0$$

$$\text{COUNTS} = [(2^{**}E) * (33 + 2 * M)] / 4, E > 0.$$

where E is the decimal value from the 4 exponent bits (the 4 MSBs of the 8 bit word), and M is the decimal value of the 4 mantissa (the 4 LSBs of the 8 bit word).

The conversion of the decompressed counts to differential number flux requires an equation of the form:

$$\text{DNF} = [\text{CTS} - \text{BKGD}] / [\text{LT} * \text{EF} * \text{G} * \text{DELTA E}]$$

where

CTS = Decompressed Counts,

BKGD = Background (preliminary value of 0 may be used),

LT = Live-time, including rate-dependent deadtime corrections that are determined from the singles counters (preliminary values of .256 for SEPA and SEPB and .512 for SEPC may be used,

EF = Efficiency factor which depends upon both the particle type and energy. This is a lookup table. A preliminary value of 1 may be used

G = Geometric factor (a preliminary value of  $3.0 \text{ E-}3 \text{ cm}^{**2}\text{-sr}$  may be used)

**DELTAE = Energy band width.**

If the Amplifier Gain bit is 1, the data is electrons. If the bit is 0, the data is protons or Alpha particles. To determine whether data is protons or Alphas, if the D Logic bit (bit 4) is 1 (for coincidence) AND the PHA lower threshold is GREATER than 60 decimal then the data is Alphas.

For the THDB, the 8 bit PCM counts are left in compressed counts form. Each record contains data from 2 major frames (8.192 seconds). The records contain status words and 2 sets of 16 spectra (and associated integral flux data) for SEPA and SEPB and one set of 16 spectra and associated integral flux data for SEPC. The spectra for the SEPA and SEPB sensors have been extracted starting on minor frame 2 of each major frame in order to align the status information with the spectra data (since there is a 2 minor frame delay in readouts for these sensors); similarly, the data from SEPC has been extracted starting at minor frame 4 of each master frame to provide the proper alignment. Thus, for SEPA and SEPB spectra, the THDB routine considers the major frame to run from minor frame 2 of the current major frame to minor frame 1 of the succeeding major frame; for SEPC the major frame runs from minor frame 4 of the current major frame to minor frame 3 of the succeeding major frame. The UT time tag placed on the THDB is associated with the start of minor frame 2 for SEPA and SEPB and with the start of minor frame 4 for SEPC.

### **16.3 PARAMETER LIST**

Each of the 3 spectrometers is uplink commandable and is capable of providing electron spectra (20-5000eV) or proton spectra (0.5-100MeV) measurements as 12 point differential flux spectra and 4 point integral flux readouts. The sensors at 80 and 60 degrees provide a full set of spectra every 0.256 s; the sensor at 40 degrees produces the 12 spectra points and 4 integral flux values every 0.512 seconds. The status word information for all sensors also included.

### **16.4 THDB DATA RECORD STRUCTURE**

The THDB files for this data consists of a header record followed by a series of data records. The header record is in 32 bit positive integer form. There is one data record every 2 major frames (8.192 seconds).

#### **HEADER RECORD (All words 32 bit integers)**

Word Number	Description
1	Experiment ID (3073)
2	Year
3	Day of Year
4	Orbit Number

5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-330	Vacant (Zero fill)

# **DATA RECORDS:**

Word No.	Description
1	UT (milliseconds) at start of minor frame associated with the first SEPA spectrum (minor frame 2)
2	Bytes 1-4: First 4 SEPA status words for this major frame
3	Bytes 1-2: Last 2 SEPA status words for this major frame
	Bytes 3-4: Vacant
4	Vacant
5-7	First SEPA spectrum for this 4.096 second interval (data stored in consecutive bytes)
8-10	2nd SEPA spectrum for this 4.096 second interval (data stored in consecutive bytes)
.	.
.	.
.	.
50-52	16th SEPA spectrum for this 4.096 second interval (data stored in consecutive bytes)
53-56	16 values of integral flux values 'DA' for this 4.096 second interval stored in byte form.
57-60	16 values of integral flux values 'EA' for this 4.096 second interval stored in byte form.
61-62	8 values of integral flux values 'AA' for this 4.096 second interval stored in byte form.
63-64	8 values of integral flux values 'EPA' for this 4.096 second interval stored in byte form.
65-128	Repeat order of words 1-64 for the next 4.096 second interval containing the SEPA data
129-256	Repeat the order of words 1-128 for the 8.192 second interval for the SEPB data. With respect to the integral flux values, the DA, EA, AA, EPA values are replaced by DB, EB, AB, and EPB, respectively.
257	UT (milliseconds) at start of minor frame associated with the first SEPC spectrum (minor frame 4)
258	Bytes 1-4: First 4 SEPC status words for this major frame
259	Bytes 1-2: Last 2 SEPC status words for this major frame
	Bytes 3-4: Vacant
260	Vacant
261-263	First SEPC spectrum for this 8.192 second interval (data stored in consecutive bytes)
264-266	2nd SEPA spectrum for this 8.192 second interval (data stored in consecutive bytes)

306-308	16th SEPC spectrum for this 8.192 second interval (data stored in consecutive bytes)
309-312	16 values of integral flux values 'DC' for this 8.192 second interval stored in byte form.
313-316	16 values of integral flux values 'EC' for this 8.192 second interval stored in byte form.
317-320	16 values of integral flux values 'AC' for this 8.192 second interval stored in byte form.
321-324	16 values of integral flux values 'EPA' for this 8.192 second interval stored in byte form.
325	<p>Byte 1: Telemetry mode flag associated with the first of the 4.096 second intervals (0 = GTO; 1 = LASSII).</p> <p>Byte 2: Telemetry mode flag associated with the second 4.096 second interval.</p> <p>Byte 3: Telemetry dropout flag associated with the first of the 4.096 second time intervals ( 0 = No dropout in the interval; 1 = dropout somewhere in the time interval)</p> <p>Byte 4: Telemetry dropout flag associated with the second of the 4.096 second time intervals ( 0 = No dropout in the interval; 1 = dropout somewhere in the time interval)</p>
326-330	Vacant

**Notes:**

1. Data obtained during LASSII telemetry mode is stored in the THDB but may be unusable. For the LASSII periods, the LASSII flag is be set to 'on' in the THDB.
2. The word order of the spectra is as it is extracted from the telemetry stream and has not been reordered to be monotonic with respect to energy. The channel order is thus, 2, 4, 6, 8, 10, 12, 1, 3, 5, 7, 9, and 11.
3. The THDB user must determine the instrument mode from the status bits (bit numbering is 7 for the MSB and bit 0 for the LSB):
  - a. If the Amplifier Gain (LSB of the 3rd status word) bit is 1, the data is electrons. If the bit is 0, the data is protons or Alpha particles. To determine whether data is protons or Alphas, if the D Logic bit (bit 4 of the 3rd status word) is 1 (for coincidence) AND the PHA lower threshold (status word 5 of the 6 status words) is GREATER than 60 decimal then the data is Alphas.

- b. The current operating page number can be obtained from the 3 LSBs of the first of the six status words.
- c. The current operating mode number within the current page may be obtained from the 3 MSBs of the second of the 6 status words.
- d. The PHA lower energy threshold can be obtained from the full 8 bit readout of the fourth of the 6 status words. Calibration data is required to convert this value to energy.
- e. The PHA upper energy threshold can be obtained from 6 MSBs of the fifth of the six status words. Calibration data is required to convert this value to energy.

## 17.0 ONR-307-8-1,-2 LOW ENERGY ION MASS SPECTROMETER (IMS-LO-1,-2)

### 17.1 INSTRUMENT DESCRIPTION

The Low Energy Ion Mass Spectrometer (IMS-LO) is designed to measure plasmas which are the sources of radiation belt particles, and to provide data on the origin and acceleration processes of these plasmas. In order to achieve these objectives, the instrument measures energy and mass spectra covering the ranges of  $E/q = 0.1\text{keV/e} - 32\text{ keV/e}$  and  $M/q$  from less than 1 to greater than 32 AMU/e with good coverage of pitch angles throughout the orbit.

These data are used to investigate plasma interaction processes including:

- 1) the plasma and field conditions that produce ionospheric acceleration, precipitation of energetic particles from the trapped populations, and VLF wave generation and amplification;
- 2) the local time and invariant latitude distributions of ionospheric ion source regions; and 3) the large-scale and small-scale transport and energization processes for the hot plasmas.

IMS-LO-1 and IMS-LO-2 are identical instruments which are mounted at 45 degrees and 75 degrees to the spacecraft spin axis in order to maximize coverage of fluxes near the magnetic field line direction. Each instrument performs ion composition measurements in the energy per charge range 0.1-32 keV/e and the mass per charge range is less than 1 to greater than 32 AMU/e. The energy

range, which is covered by 45 energy steps, is broken into three contiguous parts, each consisting of 15 energy steps. These three portions of the energy coverage are sampled in parallel by three separate analyzer and sensor heads. At the completion of each 15 step sequence, the background counting rate is measured for each sensor head. The mass range ( $< 1$  to  $> 32$  AMU/e) is covered by 32 steps. Alternatively, the spectrometer can be commanded to sample the high mass range above 16 AMU/e. In addition to ion measurements, each of the two instruments monitors the background electron flux at four fixed energies. The electron channels are described in a separate section below.

**Operating Modes.** There are two basic submodes of operation; SWEEP and LOCK.

In LOCK mode the instrument locks onto a particular M/q value while stepping in energy. Each of the 15 energy values and background are sampled for 64 ms in each of the three heads, giving a 45 point energy spectrum for a particular species in 1.024 seconds (approximately 12 degrees of spacecraft rotation). The LOCK submode obtains 32 consecutive energy spectra at a fixed mass value (approximately one spacecraft rotation) before moving into the next submode.

In SWEEP submode, the instrument sequentially "sweeps" through the 32 step mass range at each of the 15 energy steps and background. A mass sweep at one energy step requires 2.084 seconds. The entire 32.768 second SWEEP submode obtains a complete sampling of the 32x48 mass-energy array (32x16 in each of the three heads). As in the LOCK submode, 3 of the 48 energy points are actually background measurements (1 in each head).

The duration of each of the submodes is 32.768 seconds, approximately one spacecraft spin. The submodes may be combined to form the three basic modes of operation: LOCK-ONLY, SWEEP-ONLY, and SWEEP-LOCK. As the names imply, LOCK-ONLY consists of LOCK submodes only, SWEEP-ONLY is composed of SWEEP submodes, and SWEEP-LOCK alternates between SWEEP and LOCK. In either the LOCK-ONLY or SWEEP-LOCK modes, the mass channels used for the LOCK submode are sequentially executed from four values commanded into the instrument memory. These values may select any four of the 32 M/q steps corresponding to any four ion species; for instance, H<sup>+</sup>, He<sup>+</sup>, He<sup>++</sup>, O<sup>+</sup>; or H<sup>+</sup>, O<sup>+</sup>, H<sup>+</sup>, O<sup>+</sup>; or O<sup>+</sup>, O<sup>+</sup>, O<sup>+</sup>, O<sup>+</sup>. IMS-LO-1 and IMS- LO-2 are commanded independently so that it is possible to have the two instruments operating in different modes simultaneously.

In addition to the normal range of mass coverage, the instrument can be commanded into a Heavy Ion Mode. In this mode, the MA voltages are reduced by a factor of four, scaling the M/q coverage upward by a factor of sixteen.

**Electron Detectors.** Each of the IMS-LO instruments contains a set of four broad band, fixed-energy electron detectors which are

used to monitor electron fluxes between 50eV and 25keV. The  $\{\Delta\}E/E$  for each detector is 50% and the central energies of the four electron channels on IMS-LO-1 and IMS-LO-2 are interleaved, providing a total of eight channels with central energies from 0.067keV to 20keV. The electron detectors accumulate for 512 ms, providing samples approximately every 6 degrees of spacecraft spin.

## 17.2 REDUCTION PROCEDURES

The ONR 307-8-1 and 307-8-2 instruments are two identical low energy ion mass spectrometers mounted at 45 degrees and 75 degrees, respectively, to the spin axis of the vehicle. The prime science to telemetry data for each instrument consists of seven words per minor frame. One status word for each instrument is located on subcom 17 but a full set of status bits is readout over 8 major frames for each instrument. The words occurring at the minor frame rate and subcom word have the same telemetry designations; S39 for 307-8-1 and S40 for 307-8-2.

The subcommutated values for S39 and S40 are located on subcom 17 subframe 15 and subcom 17 subframe 16, respectively. The S39 minor frame data is located on minor frame words 13, 45, 77, 109, 141, 173, and 205. The S40 minor frame data is located on minor frame words 22, 54, 86, 118, 150, 182, and 214.

The instruments operate in sync with the spacecraft clock.

Lock mode produces energy spectra for fixed masses; sweep mode produces mass spectra for fixed energies. Energy range for the instruments is approximately 0.1-32 KeV; mass range is 1-32 amu. Each mode also produces an 8 point electron spectra (67eV-20keV); four points from each detector.

For each instrument, there are 3 sensor heads. Each head has 15 energy channels and a background channel. Using the labeling convention E1 to E45 for the 45 energy channels (with E0 as background), the energy steps associated with each head are as follows:

HEAD 1	HEAD 2	HEAD 3
1 - 15	16 - 30	31 - 45.

The energies for each of these steps is given by the equation:

$$E_n = (0.109 \text{ keV}) * (1.14008)^{(n-1)}, \quad n = 1, 45.$$

There are 32 mass steps (1 through 32). Provisionally, O+=step 4 and H+ = step 27. These step numbers may require further refinement once on-orbit data is obtained.

Each sensor has 4 electron channels for differential flux measurements. The data from the 2 sensors can be combined to

produce an 8 point differential electron flux spectrum. The energy channels associated with each sensor are as follows:

IMS-LO-1	CHANNEL	IMS-LO-2
150eV	1	67eV
770eV	2	340eV
3930eV	3	1740eV
20000eV	4	8880eV.

The instrument modes are SWEEP, LOCK, and SWEEP-LOCK. The full instrument cycle requires 8 major frames (to accommodate SWEEP-LOCK mode) and the beginning of a cycle is synched to the frame on which the 8 LSBs of the spacecraft clock are zero.

The digital minor frame telemetry for the sensors is in 8 bit compressed form. The compressed structure is

yyyyxxxx

where

yyyy = exponent (E)

and

xxxx = mantissa (M).

The decompression algorithm is:

COUNTS = M , E=0

COUNTS = [(2\*\*E)\*(33 + 2\*M)]/4 , E>0.

where E is the decimal value from the 4 exponent bits , and M is the decimal value of the 4 mantissa bits.

In sweep mode, 32 mass spectra are produced for the 48 energies (which includes the 3 background values) over 8 major frames. The technique used is to fix one energy for each head, obtain the three 32 point mass spectra, and then step to another energy and repeat the procedure. Thus, a mass spectrum is obtained for each fixed energy every 16 minor frames.

The order of the sweep mode readouts for the seven S39 (or S40) words is as follows:

Frame	WORD 1	WORD 2 (HEAD1)	WORD 3 (HEAD2)	WORD 4 (HEAD3)	WORD 5 (HEAD1)	WORD 6 (HEAD2)	WORD 7 (HEAD3)
0	e1	M0	M0	M0	M0	M0	M0
1	e2	M0	M0	M0	M0	M0	M0
2	e3	M0	M0	M0	M0	M0	M0
3	e4	M0	M0	M0	M0	M0	M0
4	e1	M0	M0	M0	M0	M0	M0
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
15	e4	M0	M0	M0	M0	M0	M0
16	e1	M1	M1	M1	M2	M2	M2



17	e2	M3	M3	M3	M4	M4	M4
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
31	e4	M31	M31	M31	M32	M32	M32
0	e1	M32	M32	M32	M31	M31	M31
1	e2	M30	M30	M30	M29	M29	M29
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
31	e4	M31	M31	M31	M32	M32	M32

Each of the 16 energy steps is held constant for 16 minor frames. The order of the sampling for the 16 energy steps on each head is E0 (background), E2, E4, E6, ..., E14, E15, E13, E11, ..., E3, E1. The order of the mass steps is M0 (corresponding to the background measurement for the first 16 minor frames of an 8 major frame instrument cycle), then M1 through M32 followed by M32 through M1. This pattern of reversing the order of the masses is repeated throughout the cycle.

The mass spectrum is not simultaneously acquired. Each triplet (M(i),M(i),M(i)) is simultaneously taken but the next triplet is taken 1/2 minor frame later.

In lock mode, four masses are selected by ground command. Each selected mass is held for 8 major frames and a series of 45 point (48 points counting the background readouts from each of the three heads) differential flux spectra are produced. Each full spectrum is acquired over 8 minor frames. Thus, for the 8 major frame cycle, 32 energy spectra are produced for a fixed mass. The next mass, in sequence is then taken. This cycle then continues until changed by ground command. During the 8 major frame cycle for each mass, sixty-four 8 point electron spectra also obtained. The 8 point spectrum are made up of 4 points from each of the two sensors. The order of the data readout in lock mode is summarized below.

FRAME	WORD 1	WORD 2 (HEAD1)	WORD 3 (HEAD2)	WORD 4 (HEAD3)	WORD 5 (HEAD1)	WORD 6 (HEAD2)	WORD 7 (HEAD3)
0	e1	E0	E0	E0	E2	E2	E2
1	e2	E4	E4	E4	E6	E6	E6
2	e3	E8	E8	E8	E10	E10	E10
3	e4	E12	E12	E12	E14	E14	E14
4	e1	E15	E15	E15	E13	E13	E13
5	e2	E11	E11	E11	E9	E9	E9
6	e3	E7	E7	E7	E5	E5	E5
7	e4	E3	E7	E3	E1	E1	E1.

Note that the energies are stepped in the same way as in sweep mode. The time tagging is also the same. In particular, each triplet is simultaneously taken.

In sweep-lock mode, the instrument alternates between sweep mode and lock mode every 32 seconds. In this mode, the alternating pattern always begins with SWEEP mode. Thus, the sequence is SWEEP, LOCK(M1), SWEEP, LOCK(M2), SWEEP, LOCK(M3), SWEEP, and LOCK(M4).

There is 1 subcom word per major frame. A full set of status words is readout every 8 major frames. The status values in a 32 second block represents the instrument state in that 32 seconds.

If "Command Accepted in Last 32 Sec"=1, then the data in that 32 second block is suspect. If "sync lock"=0, then sync was lost and the data is no good. If "MODE ID"=3, then the instrument is in calibration mode (mode duration is 262 seconds). There are 4 5-bit MASS LOCK words, these represent the mass STEP NUMBERS for LOCK mode. HEAVY ION MODE is noted by a discrete. There is a 2-bit value to indicate instrument mode (SWEEP, LOCK or SWEEP-LOCK). There is also a discrete to indicate the mode for the 32 second period.

The ONR 307-8-1/-2 subcom word are summarized below:

MSTR0		TRUE CONDITION
BITS		DESCRIPTION
7		1=CMD ACCEPTED IN LAST 32.768S, 0=NO COMMAND
6		1=MEMORY INVALID, 0=MEMORY NORMAL
5		1=SYNC LOCK, 0=NO SYNC
4-3		MODE ID; 3=CAL, 2=LOCK, 1=SWEEP, 0=SWEEP/LOCK
2-0		SUBMODE ID COUNTS 0-7 TO IDENTIFY SUBMODE; ROLLS OVER EVERY 32.768 SECONDS
MSTR1		TRUE CONDITION
BITS		DESCRIPTION
7		1=SWEEP MODE, 0=LOCK MODE
6		1= HIGH VOLTAGE ENABLED, 0=DISABLED
5		1=HIGH VOLTAGE ON, 0=HV OFF
4-0		MASS STEP (0-31) (indicating the present step mass step number)
MSTR2		TRUE CONDITION
BITS		DESCRIPTION
7		1=CAL PULSER ON, 0=CAL PULSER OFF
6		SPARE
5-4		CXA-1 THRESHOLD (0-3)
3-2		CXA-2 THRESHOLD (0-3)
1-0		CXA-3 THRESHOLD (0-3)
MSTR3		TRUE CONDITION
BITS		DESCRIPTION
7-6		CME-A THRESHOLD (0-3)
5-4		CME-B THRESHOLD (0-3)
3-2		CME-C THRESHOLD (0-3)
1-0		CME-D THRESHOLD (0-3)

**MSTR4**    **COMMAND LATCH CONDITION**  
**BITS**    **DESCRIPTION**  
7-6        **MODE COMMAND** 3=SWEEP/LOCK, 2=SWEEP/SWEEP, 1=LOCK/LOCK,  
            0=SWEEP/SWEEP  
5-1        **MASS LOCK WORD-1**  
0           **MSB OF MASS LOCK WORD-2 (CONTINUES ON NEXT MAJOR FRAME)**

**MSTR5**    **COMMAND LATCH CONDITION**  
**BITS**    **DESCRIPTION**  
7-4        **4 LSBS OF MASS LOCK WORD -2**  
3           **SPARE**  
2           **1=HEAVY ION MODE, 0=NORMAL**  
1-0        **2 MSBS OF MASS LOCK WORD-3**

**MSTR6**    **COMMAND LATCH CONDITION**  
**BITS**    **DESCRIPTION**  
7-5        **3 LSBS OF MASS LOCK WORD-3**  
4-0        **MASS LOCK WORD-4**

**MSTR7**    **CONMMAND LATCH CONDITION**  
**BITS**    **DESCRIPTION**  
7           **MA HVPS CONTROL; 1=ENABLE, 0=DISABLE**  
6           **EA HVPS CONTROL; 1=ENABLE, 0=DISABLE**  
5           **BI HVPS CONTROL; 1=ENABLE, 0=DISABLE**  
4-3        **BI HV LEVEL; 3=LEVEL 3 (MAX), 2=LVL 2, 1=LVL 1, 0=LVL 0**  
2           **1=HV DISARM, 0=NORMAL**  
1           **1= HV/8, 0=NORMAL**  
0           **SPARE**

The formula for conversion of the decompressed counts (C) to flux is as follows:

$$FLUX = (C / GF / ET / RELRES / EFF / E)$$

where:

C = decompressed counts  
GF = Geometric factor (one factor for each head)  
ET = Exposure time (.052 seconds)  
RELRES = Relative Response (one value for each of the 32 possible mass steps at each energy (i.e. 45 energies per detector)).  
EFF = Efficiency (one value per energy).  
E = Energy.

The flux units are #/(cm\*\*2/sec/sr/keV).

The THDB consists of a pre-processed file structured for input to follow-on analysis routines designed to determine flux. Each record contains the 8 major frames of data for each of the two IMS-LO sensors.

### 17.3 PARAMETER LIST

The THDB file for the two IMS-LO sensors consists of a pre-processed file. The file contains all the data for telemetry designation S39 (IMS-LO-1) as well as telemetry designation S40 (IMS-LO-2). In addition, the file contains telemetry dropout flags and LASSII telemetry mode flags.

The time tag associated with each major frame block is the time at the start of the major frame on which the data was readout to telemetry. Due to a double buffer system, the data was accumulated during the previous 8.192 second interval.

The 8 subcommutated values of S39 (and S40) represent the instrument status words. The minor frame values of S39 (and S40) represent the spectra data. The first of the seven words on each minor frame contains the electron spectra data and the remaining 6 words contain the ion mass spectrometer data.

Depending on the mode, various parameters are available:

**SWEEP MODE.** For a fixed energy, a 32 point mass spectrum is obtained. There are 48 energies which are stepped through. The mode duration is 32.768 s. Mass range is 1 to 32 AMU's. An 8 point electron spectrum is also produced.

**LOCK MODE.** For a fixed mass, a 45 point differential flux spectrum and 3 background readouts are obtained. Four masses are selected by ground command and they are sequentially stepped through. Each selected mass is held for 32.768 s. One full spectrum is obtained every 1.024 s. Energy range is 0.1-32keV. Eight point electron spectra are produced along with the ion spectra.

**SWEEP-LOCK mode.** Alternates between SWEEP and LOCK modes every 32.768 seconds (8 major frames).

**HIGH MASS RANGE mode.** Multiplies mass range by a factor of 16 (oxygen to barium). This can be used in conjunction with SWEEP, LOCK and SWEEP-LOCK modes.

**ELECTRON SPECTRA:** Four point electron spectra are obtained for each of the IMS-LO sensors. These may be combined from the 2 sensors to produce an 8 point spectrum. The energy range for the 8 point spectrum is approximately 67eV - 20keV. These spectra are produced independent of IMS-LO operating mode.

#### 17.4 THDB DATA RECORD STRUCTURE

The THDB files for this data consist of a header record followed by a series of data records. The header record is in 32 bit positive integer form. There is one data record every 8 major frames (32.768 sec). The data records contain the full set of

telemetry designation S39 (IMS-LO-1) and S40 (IMS-LO-2) data along with telemetry dropout and LASSII telemetry mode flags.

# HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (307812)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-910	Vacant (Zero fill)

## DATA RECORDS:

Word No.	Description
1	UT (milliseconds) at start of first major frame
2	Byte 1(MS byte): S39 from minor frame 0
	Byte 2 S39 from minor frame 0
	Byte 3 S39 from minor frame 0
	Byte 4 S39 from minor frame 0
3	Byte 1(MS byte): S39 from minor frame 0
	Byte 2 S39 from minor frame 0
	Byte 3 S39 from minor frame 0
	Byte 4 S39 from minor frame 1
4	Byte 1(MS byte): S39 from minor frame 1
	Byte 2 S39 from minor frame 1
	Byte 3 S39 from minor frame 1
	Byte 4 S39 from minor frame 1
.	.
.	.
.	.
57	Byte 1(MS byte): S39 from minor frame 31
	Byte 2 S39 from minor frame 31
	Byte 3 S39 from minor frame 31
	Byte 4 S39 from minor frame 31
58	Byte 1(MS byte): S40from minor frame 0
	Byte 2 S40from minor frame 0
	Byte 3 S40from minor frame 0
	Byte 4 S40from minor frame 0
59	Byte 1(MS byte): S40from minor frame 0
	Byte 2 S40from minor frame 0
	Byte 3 S40from minor frame 0
	Byte 4 S40from minor frame 1
60	Byte 1(MS byte): S40from minor frame 1
	Byte 2 S40from minor frame 1
	Byte 3 S40from minor frame 1
	Byte 4 S40from minor frame 1
.	.
.	.

113	Byte 1 (MS byte):	S40from minor frame 31
	Byte 2	S40from minor frame 31
	Byte 3	S40from minor frame 31
	Byte 4	S40from minor frame 31
114	UT (milliseconds) at start of 2nd major frame	
115	Byte 1 (MS byte):	S39 from minor frame 0
	Byte 2	S39 from minor frame 0
	Byte 3	S39 from minor frame 0
	Byte 4	S39 from minor frame 0
116	Byte 1 (MS byte):	S39 from minor frame 0
	Byte 2	S39 from minor frame 0
	Byte 3	S39 from minor frame 0
	Byte 4	S39 from minor frame 1
117	Byte 1 (MS byte):	S39 from minor frame 1
	Byte 2	S39 from minor frame 1
	Byte 3	S39 from minor frame 1
	Byte 4	S39 from minor frame 1
.	.	.
.	.	.
.	.	.
169	Byte 1 (MS byte):	S39 from minor frame 31
	Byte 2	S39 from minor frame 31
	Byte 3	S39 from minor frame 31
	Byte 4	S39 from minor frame 31
170	Byte 1 (MS byte):	S40from minor frame 0
	Byte 2	S40from minor frame 0
	Byte 3	S40from minor frame 0
	Byte 4	S40from minor frame 0
171	Byte 1 (MS byte):	S40from minor frame 0
	Byte 2	S40from minor frame 0
	Byte 3	S40from minor frame 0
	Byte 4	S40from minor frame 1
172	Byte 1 (MS byte):	S40from minor frame 1
	Byte 2	S40from minor frame 1
	Byte 3	S40from minor frame 1
	Byte 4	S40from minor frame 1
.	.	.
.	.	.
.	.	.
226	Byte 1 (MS byte):	S40from minor frame 31
	Byte 2	S40from minor frame 31
	Byte 3	S40from minor frame 31
	Byte 4	S40from minor frame 31
227-339	Repeat order of words 1-113 for 3rd major frame	
340-452	Repeat order of words 1-113 for 4th major frame	
453-565	Repeat order of words 1-113 for 5th major frame	
566-678	Repeat order of words 1-113 for 6th major frame	
679-791	Repeat order of words 1-113 for 7th major frame	
792-904	Repeat order of words 1-113 for 8th major frame	
905	Byte 1: (MS byte)	S39 subcom from major frame 1
	Byte 2:	S39 subcom from major frame 2
	Byte 3:	S39 subcom from major frame 3
	Byte 4:	S39 subcom from major frame 4

906           Byte 1: (MS byte) S39 subcom from major frame 5  
               Byte 2: S39 subcom from major frame 6  
               Byte 3: S39 subcom from major frame 7  
               Byte 4: S39 subcom from major frame 8  
 907           Byte 1: (MS byte) S40 subcom from major frame 1  
               Byte 2: S40 subcom from major frame 2  
               Byte 3: S40 subcom from major frame 3  
               Byte 4: S40 subcom from major frame 4  
 908           Byte 1: (MS byte) S40 subcom from major frame 5  
               Byte 2: S40 subcom from major frame 6  
               Byte 3: S40 subcom from major frame 7  
               Byte 4: S40 subcom from major frame 8  
 909           Byte 1:   Telemetry dropout flags for the 8 major  
                          frames (bit 7 (msb) for first major  
                          frame; bit 0 for 8th major frame) where  
                          a 0 bit indicates no dropout within the  
                          major frame and a 1 bit indicates  
                          dropout somewhere within the major  
                          frame.  
               Byte 2:   LASSII flag (where a value of 1 in this  
                          byte indicates LASSII telemetry mode has  
                          been detected and the data in this group  
                          of 8 major frames is most likely invalid  
                          and that a data gap follows)  
               Bytes 3 and 4 are vacant (zero fill)  
 910           Vacant (zero fill)

## 18.0   ONR-307-8-3 MEDIUM ENERGY ION MASS SPECTROMETER (IMS-HI)

### 18.1   INSTRUMENT DESCRIPTION

The primary objective of the ONR-307 instrument complement is to obtain the necessary data to construct models of the energetic particle and plasma environment of the Earth's radiation belts. The Medium Energy Ion Mass Spectrometer (IMS-HI) addresses this objective by measuring both the energetic ion composition energy spectra and pitch angle distributions, and the energetic neutral particle energy spectra and pitch angle distributions, with good mass, temporal, spatial and energy resolution. The IMS-HI instrument is located at an angle of 75 degrees to the spin axis to maximize pitch angle sampling. The ion energy range is approximately 20 to 8000 keV-AMU/q<sup>2</sup>.

The IMS-HI instrument is designed to extend the energy range of ion composition measurements well above that of the traditional IMS-LO instruments which are also part of the ONR-307 Experiment. The principle of operation of the IMS-HI instrument is based on ion momentum separation in a magnetic field followed by energy and mass defect analysis using an array of cooled silicon solid state sensors.

The IMS-HI instrument features a parallel architecture with simultaneous mass and energy analysis at relatively high sensitivity.

The principle of operation of this instrument is based on ion momentum separation in a magnetic field followed by energy and mass defect analysis using an array of cooled silicon solid state sensors. The entrance collimator defines the ion beam angular resolution using a series of rectangular baffles and includes a broom magnet to reject electrons with energy less than one MeV.

At the collimator exit, an annular solid-state detector with a central hole is used to measure the integral ion and neutral energy spectrum of the beam supplied to the magnet for momentum analysis. A 7 kilogauss magnetic field is then used to disperse the collimated ions onto a set of six passively cooled (-50 degrees C) silicon surface barrier detectors. The energy range, which varies with ion species, is approximately  $EM/q^2 = 20-8000$  keV-AMU/ $q^2$ . A seventh sensor, located directly in line with the collimator, measures energetic neutrals (ion rejection is approximately 100 MeV-AMU/ $q$ ).

There are two basic modes of instrument operation; mass lock and mass scan.

#### **MASS LOCK and MASS SCAN MODES.**

In the Mass Scan Mode (also called energy mode), each of the seven solid state sensors is pulse-height analyzed into 256 levels of which 64 intervals are accumulated in memory and read out every eight seconds. This mode is used to scan all mass peaks within the range of the sensor relative to the background continuum.

In the Mass Lock Mode (also referred to as mass mode) each of the seven solid state sensors is pulse height analyzed into 256 levels of which four intervals (typically, four ions) are accumulated in memory and read out every half second. This mode is used for making rapid spectral snapshots of four ions as a function of pitch angle.

Baseline operation of the instrument is a toggle mode between Mass Lock Mode and Mass Scan Mode every 32.768 seconds.

#### **18.2 REDUCTION PROCEDURES**

There are 9 words per minor frame located on telemetry designation S41 (minor frame word numbers are 19, 51, 83, 115, 147, 179, 211, 237, and 243). Seven of these words are for spectra and 2 are for singles readouts (minor frame words 19 and 51). The singles channels are not used directly in the analysis but were included in the event that they could be useful in identifying events and thus they are stored in the THDB. In



addition, there are 8 subcom words per master frame (also designated S41; telemetry word locations are subcom 17, subframes 17 through 24) for instrument status. Data from the instrument is readout only when the spacecraft telemetry is in GTO mode. There are 6 detectors for ion measurements and one for neutrals. There are 2 modes for the instrument; Mass Scan Mode (mass scan) and Mass Lock Mode (mass lock). The pre-launch definition of normal operations for the instrument was a 'toggle' which alternates between mass scan and mass lock mode every 8 major frames (32 seconds).

The most significant bit (bit 7) of subcom 17/ subframe 18 indicates the instrument mode (0=MASS SCAN, 1=MASS LOCK MODE). Due to the complexity of algorithm development for this sensor, the THDB consists of a preprocessed file of minor frame and subcom words. This assures that all necessary information is available for the analyses involved in converting to flux.

The 8 bit readouts on the minor frame words represent compressed counts. The Lockheed 8 bit decompression algorithm is used to decompress the 8 bit readouts into true counts. This algorithm is as follows:

$$\text{COUNTS} = M, \text{ if } E = 0$$

$$\text{COUNTS} = [(2^{**}E) * (33 + 2 * M)] / 4, \text{ if } E > 0.$$

where E is the decimal value from the 4 exponent bits (the 4 MSBs of the 8 bit word), and M is the decimal value of the 4 mantissa (the 4 LSBs of the 8 bit word) bits.

Since the instrument does not output data to telemetry when the spacecraft is LASSII mode, a flag is included in the THDB file to indicate that a data gap is forthcoming due to a switch to LASSII.

#### 18.2.1 MASS SCAN MODE

In mass scan mode, 64 point mass spectra at each of 6 energies plus neutrals are obtained every 8.192 seconds (2 major frames). The data for each of the 7 spectra are simultaneously acquired in the previous 8.192 seconds. The instrument uses a double buffer technique where one buffer is accumulating data while the other is being readout to telemetry. The time tag put into the THDB is that of the time at which the data is readout to telemetry (see note in parameter list and THDB format).

In the analysis to flux, sums of counts for channels around a mass peak may be used (e.g. sum the counts +/- 2 points around a mass peak) before calibrations are applied. The energy value associated with each mass is a function of the mass and the detector number. For instance, the approximate energy values

associated with H<sup>+</sup> and He<sup>+</sup> as a function of detectors 1 through 6 are as follows:

DET	H <sup>+</sup> (keV)	He <sup>+</sup> (keV)
1	18	4.5
2	58	15
3	140	37
4	360	90
5	1200	300
6	1700	425

The prime masses which are studied are H<sup>+</sup>, He<sup>+</sup>, O<sup>+</sup>, and O<sub>2</sub><sup>+</sup>. When in final calibrated form, the science data is in flux with units of flux/cm<sup>2</sup>/sec/sr/keV.

There is a calibration pulser mode which can be determined by use of bits on the subcom. The duration of the mode is approximately 131.072 seconds. As with all other operations of the instrument, the beginning of the calibration pulser mode initiates at the start of a 'Lockheed instrument cycle'.

#### 18.2.2 MASS LOCK MODE

In this mode, there are sixteen 6 point energy spectra plus a neutral spectrum for each of 4 selected masses every 8.192 seconds. Thus, one full set of spectra (spectra from all 7 detectors) is obtained every .512 seconds. This mode allows for rapid snapshots of the four selected masses. One of the four masses is selected by uplink command but the other three are fixed. Moreover, the order of the readouts within the telemetry is fixed. The table below reflects the readout order and the selected masses.

MASS POINT NUMBER	SELECTED MASS
1	Selectable by uplink command
2	O <sup>+</sup>
3	He <sup>+</sup>
4	H <sup>+</sup>

As with mass scan mode, the data readout to telemetry in the 8.192 second block was acquired during the previous 8.192 seconds (see note in parameter list and THDB format). The data for each of the 16 time intervals was simultaneously acquired. The time delta between readout sets (4 masses for each of the 7 detectors) is .512 seconds.

The counts data associated with each mass actually represents the counts at (and possibly the sum of counts around) a given mass peak. The points used in the sum is a commandable feature of the instrument and on-orbit experience with the sensor was required in order to determine the optimum technique to be used.

As with mass scan mode, the energy associated with a given mass is function of the mass number and detector. Tables as described in the Mass Scan Mode write-up are used to associate energy with the flux readouts for the selected masses as a function of detector number.

The order of the channel readouts for each detector is:

64 channels for detector 1

64 channels for detector 2

.

.

.

64 channels for detector 7 (neutrals).

Thus 64 minor frames are required for the full readout. This corresponds to 8.192 seconds.

# ONR 307-8-3 - MASS SCAN MODE TELEMETRY

Minor Frame	Word Number							
	1	2	3	4	5	6	7	8
0	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D1B	D1A	CH0	CH1	CH2	CH3	CH4	CH5
1	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D2B	D2A	CH7	CH8	CH9	CH10	CH11	CH12
2	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D3B	D3A	CH14	CH15	CH16	CH17	CH18	CH19
3	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D4B	D4A	CH21	CH22	CH23	CH24	CH25	CH26
4	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D5B	D5A	CH28	CH29	CH30	CH31	CH32	CH33
5	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D6B	D6A	CH35	CH36	CH37	CH38	CH39	CH40
6	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D7B	D7A	CH42	CH43	CH44	CH45	CH46	CH47
7	LOOK DATA	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	1	2	CH46	CH50	CH51	CH52	CH53	CH54
8	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D1B	D1A	CH56	CH57	CH58	CH59	CH60	CH61
9	SINGLES	DET1	DET2	DET2	DET2	DET2	DET2	DET2
	D2B	D2A	CH63	CH0	CH1	CH2	CH3	CH4
10	SINGLES	DET2	DET2	DET2	DET2	DET2	DET2	DET2
	D3B	D3A	CH6	CH7	CH8	CH9	CH10	CH11
11	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D4B	D4A	CH13	CH14	CH15	CH16	CH17	CH18
12	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D5B	D5A	CH20	CH21	CH22	CH23	CH24	CH25
13	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D6B	D6A	CH27	CH28	CH29	CH30	CH31	CH32
14	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	D7B	D7A	CH34	CH35	CH36	CH37	CH38	CH39
15	LOOK DATA	DET1	DET1	DET1	DET1	DET1	DET1	DET1
	3	4	CH41	CH42	CH43	CH44	CH45	CH46

There are 2 singles readouts from each of the 7 detectors every 7 minor frames plus look data in the 8th minor frame.

**OMR 307-8-3 - MASS LOCK MODE TELEMETRY**  
Word number

Minor frame	1	2	3	4	5	6	7	8	9
0	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D1B	D1A	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN2	CHAN2
		INT1	INT1	INT1	INT1	INT2	INT2	INT2	
1	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D2B	D2A	CHAN3	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN1
		INT2	INT3	INT3	INT3	INT3	INT4	INT4	
2	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D3B	D3A	CHAN2	CHAN3	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN0
		INT4	INT4	INT5	INT5	INT5	INT5	INT6	
3	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D4B	D4A	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN2	CHAN3	CHAN3
		INT6	INT6	INT6	INT7	INT7	INT7	INT7	
4	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D5B	D5A	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN2	CHAN2
		INT8	INT8	INT8	INT8	INT9	INT9	INT9	
5	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D6B	D6A	CHAN3	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN1
		INT9	INT10	INT10	INT10	INT10	INT11	INT11	
6	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D7B	D7A	CHAN2	CHAN3	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN0
		INT11	INT11	INT12	INT12	INT12	INT12	INT13	
7	LOOK DATA	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
1	2	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN2	CHAN3	CHAN3
		INT13	INT13	INT13	INT14	INT14	INT14	INT14	
8	SINGLES	DET1	DET1	DET1	DET1	DET1	DET1	DET1	DET1
D6B	D6A	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN2	CHAN2
		INT15	INT15	INT15	INT15	INT16	INT16	INT16	
9	SINGLES	DET1	DET2	DET2	DET2	DET2	DET2	DET2	DET2
D7B	D7A	CHAN3	CHAN0	CHAN1	CHAN2	CHAN3	CHAN0	CHAN1	CHAN1
		INT16	INT1	INT1	INT1	INT1	INT2	INT2	

The above pattern continues for the 7 detectors, 4 masses (channels), and 16 time intervals (INT). The instrument reads out 4 masses for each detector over 16 time intervals (INT). So,

over 2 major frames, there are 16 spectra. A spectrum is obtained for all 7 detectors every .512 seconds (8 minor frames).

#### ONR 307-8-3 SUBCOM DATA

There are 8 subcom words per major frame.

##### WORD 0

BITS	DESCRIPTION
7	1=CMD ACCEPTED PREVIOUS MAJOR FRAME, 0=NO CMD
6	1=MEMORY INVALID, 0=MEMORY NORMAL
5	1=LOAD LOCK, 0=NORMAL
4	1=SYNC LOCK; 0=NO SYNC
3	1=MEMORY CHECK IN PROGRESS (NEEDS 8.096S TO DO), 0=NORMAL
2	1=HIGH VOLTAGE ON, 0=OFF
1	1=CAL ON (RUNS ON 131 S BOUNDARY FOR 131 S), 0=CAL OFF
0	1=CAL LOCKOUT, 0=CAL NORMAL

##### WORD1

BITS	DESCRIPTION
7	1=MASS LOCK MODE, 0=MASS SCAN MODE
6	READOUT MEMORY ID (TOGGLES EVERY 8.196S) 1=MEM-B, 0=MEM-A
5	LOOKUP TABLE ID; 1=MASS TABLE, 0=ENERGY TABLE (COMBINE WITH WORD 7).
4	SCALAR OVERFLOW IN PREV 4.096S; 1=OVERFLOW, 0=NORMAL
3	STRETCHER GATE CONTROL; 1=NORMAL, 0=CONTINUOUS ENABLE
2-0	VACANTS

##### WORD 2

BITS	DESCRIPTION
7-0	DISCRIMINATOR-A THRESHOLD (REPRESENTED AS 2 DIGIT HEX EQUIV)

##### WORD3

BITS	DESCRIPTION
7-0	DISCRIMINATOR-B THRESHOLD (REPRESENTED AS 2 DIGIT HEX EQUIV)

##### WORD4

BITS	DESCRIPTION
7-0	DISCRIMINATOR-C THRESHOLD (REPRESENTED AS 2 DIGIT HEX EQUIV)

##### WORD5

BITS	DESCRIPTION
7	I2 HV CONTROL; 1=INHIBIT, 0=ENABLE
6-4	I2 HV LEVEL (LEVEL 7=MAX)
3	I1 HV CONTROL; 1=INHIBIT, 0=ENABLE
2-0	I1 HV LEVEL (LEVEL 7=MAX)

##### WORD6

BITS	DESCRIPTION
7	N HV CONTROL
6-4	N HV LEVEL
3-0	SPARES

##### WORD7

BITS	DESCRIPTION
------	-------------

7-0      LOOKUP TABLE START ADDRESS (FROM MEM LOCATIONS IN SAME  
         MASTER FRAME) REPRESENTED AS 2 DIGIT HEX EQUIVALENT

### 18.3    PARAMETER LIST

The THDB file for this sensor consists of a pre-processed file containing all minor frame and subcommutated words necessary for analysis of the data. Each record contains data accumulated over 8 major frames. The subcommutated data reflecting the instrument mode appears two major frames (8.192 seconds) before the accumulated science data is readout. The THDB routine aligns the status information with the science data output to facilitate input to follow-on analysis routines.

The information below reflects the information which can be derived from the THDB by follow-on analysis routines.

#### MODES/PARAMETERS

- i)    Mass Lock Mode - For 4 fixed (commandable) masses, 6 point differential flux ion spectra and a neutral read out are obtained. The energy range of the spectra varies with mass, e.g., H<sup>+</sup> is approximately 30 keV to 2.5 MeV; He<sup>+</sup> is approximately 7 keV to 1 MeV. Time duration for these spectra is 0.512 seconds.
- ii)   Mass Scan Mode - 64 point mass spectra has 7 energies. Time duration is 8.192 seconds.
- iii) Sweep-Lock (mass scan - mass lock) - alternates between scan and lock every 8 major frames (32.768 seconds).
- iv)   The two singles counters associated with each of the 7 detector elements.
- v)    The subcommutated data.
- vi>   Data flag to indicate that a telemetry mode switch from GTO to LASSII is forthcoming.

### 18.4    THDB DATA RECORD STRUCTURE

The THDB files for this data consist of a header record followed by a series of data records. The header record is in 32 bit positive integer form. There is one data record every 8 major frames (32.768 seconds). The status information contained on the subcommutator precedes the science data by two major frames within the telemetry stream. In the THDB generation, the status information has been realigned with the science output.

**HEADER RECORD** (All words 32 bit integers)

Word Number	Description
1	Experiment ID (30783)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-604	Vacant (Zero fill)

#### DATA RECORDS:

Word No.	Description
1	UT (milliseconds) at start of first major frame
2	Byte 1: Subcom 17 subframe 17 Byte 2: Subcom 17 subframe 18 Byte 3: Subcom 17 subframe 19 Byte 4: Subcom 17 subframe 20
3	Byte 1: Subcom 17 subframe 21 Byte 2: Subcom 17 subframe 22 Byte 3: Subcom 17 subframe 23 Byte 4: Subcom 17 subframe 24
4	Bytes 1-4: Minor frame words 19, 53, 83, 115 from MF0
5	Bytes 1-4: Minor frame words 147, 179, 211, 237 from MF 0
6	Byte 1: Minor frame word 243 from MF0 Bytes 2-4: Minor frame words 19, 53, 83 from MF1
7	Bytes 1-4: Minor frame words 115, 147, 179, 211 from MF1
.	.
.	.
.	.
75	Bytes 1-4: Minor frame words 179, 211, 237, 243 from MF 31.
76-150	Repeat order of words 1-75 for 2nd major frame
151-225	Repeat order of words 1-75 for 3rd major frame
.	.
.	.
.	.
526-600	Repeat order of words 1-75 for 8th major frame
601	Telemetry mode flags (0 = GTO, 1 = LASSII): Byte 1: Telemetry mode flag for 1st major frame Byte 2: . . . 2nd . Byte 3: . . . 3rd . Byte 4: . . . 4th .
602	Bytes 1-4: Telemetry mode flags associated with major frames 5-8
603	Telemetry dropout flags (0 = no dropout, 1 = dropout) Byte 1: Telemetry dropout flag associated with 1st major frame

Byte 2: Telemetry dropout flag associated with  
2nd major frame  
Byte 3: Telemetry dropout flag associated with  
3rd major frame  
Byte 4: Telemetry dropout flag associated with  
4th major frame  
604 Bytes 1-4: Telemetry dropout flags associated with  
major frames 5-8.

**Note:**

1. The realignment of the status information with the science data has been accomplished as follows:

Since there are 8 major frames per record on the Agency file, the status (subcommutated words) from major frame 1 are selected and associated with major frame 3 of the 8 major frames. This process continues through the 32 second interval. Thus, while the status data is taken from major frames 1 through 8 on an Agency Tape record, the minor frame data for the 32 second interval is taken from major frame 3 of record N through record 2 of record N+1. The time tags for the major frame data are those associated with major frames 3 of record N through major frame 2 of record N+1. This procedure causes the data contained in the first two major frames of an orbit to be lost; but the instrument status for this data is unknown anyway.

## **19.0 ONR-604 ISOTOPES AND SOLAR FLARES**

### **19.1 INSTRUMENT DESCRIPTION**

The overall scientific objectives of the Experiment for High Energy, Heavy Nuclei Composition (ONR-604) are:

1. To obtain new data on the isotopic and elemental composition of high energy, heavy charged particles which assists in understanding the high energy conversion processes in solar flares
2. To discover observable solar conditions leading up to the explosive phase of a solar flare, and
3. To determine the high energy, heavy ion fluxes in selected regions of the magnetosphere in order to determine the importance of this component as a source of radiation damage and "soft upsets" in electronic devices.

More specifically, the primary objectives of this experiment are:



1. To study solar flare energy conversion and high energy particle acceleration mechanisms on the sun
2. To monitor solar flare particle flux levels
3. To measure the high energy galactic cosmic ray composition as a "template" for solar flare observations, and
4. To determine the composition of any heavy ions observed in the magnetosphere.

Secondary objectives include:

1. Examination of constraints imposed on stellar nucleosynthesis models and their application to the sun.
2. Determination of parameters for models of the origin, acceleration, and propagation of charged particles into the earth's magnetosphere
3. Study of the access of solar particles into the earth's magnetosphere
4. Determination of trapping times for particles observed in the magnetosphere, and
5. Space flight verification of the new technology embodied in the solid-state position sensing detectors.

## 19.2 REDUCTION PROCEDURES

The ONR-604 data is readout in GTO and CSM telemetry modes only; no data is obtained during LASSII telemetry mode. The brief summary of instrument telemetry is as follows:

Serial Digital (S42)	12 WORDS/MINOR FRAME
Analog (A293,A294)	2 WORDS/MAJOR FRAME
Bilevels (B33)	3 BITS/MAJOR FRAME

The main telemetry consists of 12 words per minor frame. Four minor frames are required for an 'event' (a full set of readouts). The four minor frames are synced to the subframe ID and always start at subframe 0 (MOD 4). The data from the 4 minor frames can be deconvolved as follows:

20	12 bit words
1	7 bit word
13	8 bit words
3	Vacant 8 bit words.

S42 is readout in GTO and CSM modes only. The 12 S42 words per minor frame are contained on minor frame word numbers: 25, 57, 89, 121, 153, 156, 185, 188, 217, 220, 249, and 252.

The instrument can be operated in three modes: proton mode, heavy ion (normal) mode, and in calibration mode.

ONR-604 personnel were to decide on 'routine operations' after studying on-orbit data. During the exploratory phase, normal mode is used while the spacecraft enters perigee from a given value of L-Shell (say  $L = L_1$ ) exits perigee back to  $L = L_1$ . Proton mode is used outside  $L = L_1$ . In normal mode, the instrument threshold is increased by about a factor of 4. Mode switching can be performed only by uplink command; there is no automatic internal mode switching.

The P channels, P1, P2, and P3, can be used to obtain count rates over wide energy and mass ranges:

P3 measures mainly protons from 40 to about 600 MeV/nucleon. The proton component is present only when the instrument is being operated in proton mode.

P2 represents the count rate for Helium through Neon in the energy range from approximately 45-200 MeV/Nucleon. Most of the P2 count rate is Helium.

P1 represents the count rate for Neon through Iron in the energy range greater than 100 MeV/nucleon.

The algorithm for conversion of the telemetry data for P1, P2, and P3 to count rate is straight forward:

$$\text{COUNT RATE}(i) = f(P_i)$$

where  $f(P_i)$  is a simple log-decompression algorithm.

In the succeeding descriptions in this section, the telemetry minor frame numbers are taken to be MODULO 4; the bit numbering is such that bit 7 = MSB and bit 0 = LSB of each telemetry byte.

The prime ONR-604 data for the THDB consists of the count rates from the P channels. Additional parameters have been included in the THDB but these are for in-house use at PL in support of the MEP.

When the instrument is in proton mode, the ONR-604 discrete 'PROTON COMMAND' (located on instrument subframe 2, word 220, bit 3) is set to 1; when the value of that discrete is 0, the instrument is in heavy ion mode. Calibration mode is in progress if the ONR-604 discrete 'CAL TOGGLE' (instrument subframe 2, word 220, bit 7) is set to equal to 1.

The instrument MUX number must be extracted in order to determine the subframes, within the telemetry major frame, from which to extract the P1, P2, and P3 channels. The MUX value is located on instrument subframe 2 [telemetry minor frame 2 (modulo 4)], telemetry word 188, bits 3-1. The MUX number cycles through the numbers 0 through 7 over a major frame, but the first MUX number in the major frame may not be zero, i.e. the sequence could be 3, 4, 5, 6, 7, 0, 1, and 2. The subcom level number is stored on the data base since it is required in order to determine the singles channel being readout on a major frame. It is located in bits 7-4 on word 188 of telemetry minor frame 2. It's value remains constant for an entire major frame. The telemetry information for the P channels is stored in instrument designations R1 and R2 in exponent and mantissa form. Both the exponent and mantissa consist of 5 bits.

The R1 and R2 bit locations are always on instrument subframe 3. The bit locations are as follows:

R1 exponent	Word 185 bits 3-0 and word 188 bit 7
R1 mantissa	Word 188 bits 6-2
R2 exponent	Word 188 bits 1-0 and word 217 bits 7-5
R2 mantissa	Word 217 bits 4-0.

P1, P2, P3, and the SINGLES data are to be extracted from the R1 or R2 locations based on MUX number:

	MUX	R value
P3	6	R2
P2	7	R1
P1	7	R2
Singles	6	R1

For the THDB, the following decompression algorithm can be applied to the exponent (Y) and mantissa (X) to obtain true counts for both the P channels and the singles channels:

1. If  $Y = 22$  and  $X = 31$ ,  $COUNTS = 0$ .
2. Otherwise  $COUNTS = 1 + (X + 32) * [2^{(N-6)}]$

where the value of N is obtained from the table below:

Y	N	Y	N	Y	N	Y	N
0	13	8	21	16	**	24	5
1	24	9	16	17	8	25	0
2	23	10	15	18	7	26	**
3	14	11	22	19	**	27	6
4	25	12	17	20	9	28	1
5	12	13	20	21	**	29	4
6	11	14	19	22	27	30	3
7	26	15	18	23	10	31	2

The values ' \*\* ' should never occur. If these values appear, the value of true counts stored in the THDB is set to 2\*\*30, which exceeds the largest allowable value.

The P1, P2 and P3 flag bits are included in the THDB and they were selected from the MUX = 7 group on instrument subframe 3. Their locations are as follows:

P1 FLAG Word 121 bit 5  
P2 Flag Word 121 bit 4  
P3 flag Word 121 bit 3.

The following instrument analog data and bilevel data is stored in the THDB in byte form:

A294 = Electronics Temperature (SUBCOM 13, SUBFRAME 8)  
A293 = Telescope Temperature (SUBCOM 13, SUBFRAME 4)  
B33 = POWER ON/OFF (SUBCOM 14, SUBFRAME 13, BITS 1-3;  
0= OFF, 7 = ON.

For B33, the full 8 bit telemetry word containing the instrument bilevels are stored in the THDB.

The pre-launch polynomial coefficients to convert A294 PCM counts to degrees C are:

A0 = 76.2129  
A1 = -1.4724  
A2 = .0093946  
A3 = .000024

The pre-launch polynomial coefficients to convert A293 PCM counts to degrees C are:

A0 = 84.92987  
A1 = -1.1957  
A2 = .00611074  
A3 = -.000013356

From pre-launch calibration data reflecting the energy deposited in the K1 detector versus the sum of the energies deposited in detectors K2 through K8, a line can be drawn to exclude helium. The form of the line is:

$$K1 \text{ (MeV)} + A * K2:K8 \text{ (MeV)} = C$$

where A and C are constants.

Then, for any event, the PHA data for the K detectors must be converted to energy for the depth of penetration (the discrete words KiL must be used to determine the depth of penetration; i.e. if K1L=K2L=K3L=1, and K4L=0 then the particle penetrated to detector K3) and sum the energies. If  $K1(\text{MeV}) + A * K2:K8 \text{ (MeV)}$

is less than C, the event is helium; if it is greater than C, the event is something other than helium. Similar techniques may be developed to draw 2 lines and, for instance, obtain count rates for the (C, N, O) band.

The detailed description of the ONR-604 telemetry is as follows:

MINOR FRAME	WORD	BIT NO	TOTAL BITS	DESCRIPTION
0	25	7-0	12	PHA-1 (E1)
	57	7-4		
	57	3-0	12	PHA-2 (P1)
	89	7-0		
	121	7-0	12	PHA-3 (E2)
	153	7-4		
	153	3-0	12	PHA-4 (P2)
	156	7-0		
	185	7-0	12	PHA-5 (E3)
	188	7-4		
	188	3-0	12	PHA-6 (P3)
	217	7-0		
	220	7-0	12	PHA-7 (K1)
	249	7-4		
	249	3-0	12	PHA-8 (K3)
	252	7-0		
1	25	7-0	12	PHA-9 (K5)
	57	7-4		
	57	3-0	12	PHA-10 (K7)
	89	7-0		
	121	7-0	12	PHA-11 (E4)
	153	7-4		
	153	3-0	12	PHA-12 (P4)
	156	7-0		
	185	7-0	12	PHA-13 (E5)
	188	7-4		
	188	3-0	12	PHA-14 (P5)
	217	7-0		
	220	7-0	12	PHA-15 (E6)
	249	7-4		
	249	7-4	12	PHA-16 (P6)

	252	7-0		
2	25	7-0	12	PHA-17 (K2)
	57	7-4		
	57	3-0	12	PHA-18 (K4)
	89	7-0		
	121	7-0	12	PHA-19 (K6)
	153	7-4		
	153	3-0	12	PHA-20 (K8)
	156	7-0		
	185	7-0	8	UNIT ID
	188	7-4	4	RATE SUB-COM
	188	3-1	3	MUX NUMBER
	188	0	1	MAG/SUN CMD
	217	7	1	CAL TOGGLE (when this bit is set, an in- flight cal is in progress)
		6	1	CAL CMD
		5	1	CAL O.R.CMD
		4	1	D1 CMD
		3	1	D2 CMD
		2	1	D3 CMD
		1	1	K1 CMD
		0	1	K2 CMD
	220	7	1	A CMD
		6	1	S CMD
		5	1	P2 CMD
		4	1	P3 CMD
		3	1	PROTON CMD (when this bit is set, the instrument is in proton mode)
		2	1	P.G. FLAG
		1	1	P.G. LEVEL
		0	1	P.G. LEVEL
	249	7	1	P.G. LEVEL
		6	1	P.G. LEVEL
		5	1	CAL PLS FLAG
		4	1	IFC (MSB) RAMP
	249	3-0	10	IFC 1024 STEPS
	252	7-2		

	252	1-0	2	IFC , NORM=11
3	25	7	1	D1
		6	1	D2
		5	1	D3
		4	1	D4
		3	1	D5
		2	1	D6
		1	1	K1L
		0	1	K2L
	57	7	1	K3L
		6	1	K4L
		5	1	K5L
		4	1	K6L
		3	1	K7L
		2	1	K8L
		1	1	A
		0	1	S
	89	7	1	K1M
		6	1	K2M
		5	1	K1H
		4	1	K2H
		3	1	K3H
		2	1	K4H
		1	1	K5H
		0	1	K6H
	121	7	1	K7H
		6	1	K8H
		5	1	P1 FLAG
		4	1	P2 FLAG
		3	1	P3 FLAG
	121	2-0	11	SECTOR
	153	7-0		
	156	7-0	12	CLOCK
	185	7-4		
	185	3-0	5	R1 'Y'
	188	7		
	188	6-2	5	R1 'X'
	188	1-0	5	R2 'Y'
	217	7-5		
	217	4-0	5	R2 'X'
	220	7-0	8	FILL BITS

249	7-0	8	FILL BITS
252	7-0	8	FILL BITS

**Note:** For word 188 on subframe 2, BITS 7-4 give the subcom number (0-15) and BITS 3-1 contain the MUX number within each major frame.

Minor Frame	MUX No	Minor Frame	R1	R2
2	0	3	D1D2	D1D2D3
6	1	7	D1D2D3D4D5	D1D2D3D5D6
10	2	11	D1D2D3K1K2	D1D2D3D5K2K3
14	3	15	D1D2D3K1K3K4	D1D2D3D5K4K5
18	4	19	D1D2D3K1K5K6	D1D2D3K1K6K7
22	5	23	D1D2D3K1K7A	D1D2D3K1K2A
26	6	27	SINGLES RATES	P3
30	7	31	P2	P1

### 19.3 PARAMETER LIST

The prime ONR-604 THDB parameters are the count rates from the P1, P2, and P3 channels as well as the singles rate data which occur once per major frame. P3 measures primarily protons from 40 to approximately 600 MeV/nucleon. For P3, the proton component is present only when the instrument is in proton mode. P2 represents the count rate for helium through neon in the energy range from approximately 45-200 MeV/nucleon. Most of the P2 count rate is helium. P1 represents the count rate for neon through iron in the energy range greater than 100 MeV/nucleon. There are 16 singles rates of which 1 is readout every major frame. It thus takes 16 major frames to get the full set of single data. The subcom ID is included in the THDB since it is needed to determine which singles value is present in a given 4.096 second period.

Data flags are included to indicate instrument mode (proton mode or heavy ion mode); when an in-flight calibration is in progress; whether telemetry dropout was present in the major frame; and to note that a data gap is present due to a switch to LASSII telemetry mode. Instrument analogs and discretes are also stored in the THDB. Additional parameters are included in the THDB, but these parameters are for in-house use at PL in support of the MEP.

One THDB record consists of data accumulated over a major frame (4.096 seconds).

### 19.4 THDB RECORD STRUCTURE



The ONR-604 THDB consists of a header record followed by a series of data records for each orbit. There is one record per major frame (4.096 seconds).

#### HEADER RECORD (All words 32 bit integers)

Word Number	Description
1	Experiment ID (604)
2	Year
3	Day of Year
4	Orbit Number
5	Start Time of orbit (UT in milliseconds)
6	End Time of orbit (UT in milliseconds)
7-106	Vacant (Zero fill)

#### DATA RECORDS:

Word Number	Description
1	UT (milliseconds at the start of the major frame)
2	P1 decompressed counts
3	P2 decompressed counts
4	P3 decompressed counts
5	Singles rate (decompressed counts)
6	Subcom number
7	Byte 1: Proton CMD flag ( 0 = heavy ion mode; 1 = proton mode) Byte 2: Calibration mode flag (0 = no calibration; 1 = calibration in progress) Byte 3: Telemetry mode flag (0 = normal; 1 = data gap follows due to a switch from GTO or CSM telemetry modes to LASSII mode) Byte 4: Telemetry dropout indicator ( 0 = no dropout in this major frame; 1 = some words are 1's filled due to telemetry dropout).
8	Byte 1: A293 Byte 2: A294 Byte 3: B33 Byte 4: Bit 2 = P1 flag, bit 1 = P2 flag, bit 0 = P3 flag
9-11	Telemetry words 25, 57, 89, 121, 153, 156, 185, 188, 217, 220, 249, 252 (stored in successive bytes) from minor frame 0.
12-14	Telemetry words 25, 57, 89, 121, 153, 156, 185, 188, 217, 220, 249, 252 (stored in successive bytes) from minor frame 1.
102-104	Telemetry words 25, 57, 89, 121, 153, 156, 185, 188, 217, 220, 249, 252 (stored in successive bytes) from minor frame 31.
105-106	Vacant

**Note:** Since one singles readout is obtained every major frame, the full set of singles readouts requires 16 major frames (65.536 seconds). The information in the "singles rates" is a function of the subcom number. The table below relates the "singles rates" outputs to the subcom number.

Subcom Number	Singles Readout
0	D1
1	D2
2	D3
3	D4
4	D5
5	D6
6	K1
7	K2
8	K3
9	K4
10	K5
11	K6
12	K7
13	K8
14	A
15	S

## 20.0 EPHEMERIS DATA

Spacecraft vectors are received at PL/GPD from CSTC on a daily basis. These vectors along with magnetic field models are the prime input to the ephemeris generation routines. These routines are run prior to the Agency Tape generation process.

### 20.1 THDB DATA BASE FORMAT

Ephemeris data files are duplicates of those placed on the Agency Tapes. Data records are in 32 bit positive integer form (31 data bits and the MSB set equal to 0). Offset and bias values are provided to convert the positive integer values to true units. For altitudes less than 3 Earth Radii, the data occurs at a rate of once per minute. For higher altitudes, the rate is once per 5 minutes.

To convert the 32 bit positive integer data on the file into proper units, subtract  $2^{30}$  from the value and then multiply by the appropriate factor. All factors are in powers of 10. The table below gives the appropriate multiplicative factor for each word on the ephemeris file (e.g. if power is 2, then multiply the integer word by  $10^2$  after subtracting  $2^{30}$ ).

WORD	DESCRIPTION	FACTOR
------	-------------	--------

1	JULIAN DATE (DAYS)	0
2	UT (MILLISECONDS)	0
3	X, SATELLITE POSITION, ECI (KM)	-4
4	Y, SATELLITE POSITION, ECI (KM)	-4
5	Z, SATELLITE POSITION, ECI (KM)	-4
6	VX, SATELLITE VELOCITY, ECI (KM/SEC)	-7
7	VY, SATELLITE VELOCITY, ECI (KM/SEC)	-7
8	VZ, SATELLITE VELOCITY, ECI (KM/SEC)	-7
9	RADIUS, EARTH CENTER TO SATELLITE (KM)	-4
10	ALTITUDE (KM)	-4
11	LATITUDE (DEG)	-6
12	LONGITUDE (DEG)	-6
13	VELOCITY (KM/SEC)	-7
14	LOCAL TIME (HR)	-7
15	RADIUS, MAG (EMR)	-7
16	LATITUDE, MAG (DEG)	-6
17	LONGITUDE, MAG (DEG)	-6
18	RADIUS, SM (EMR)	-7
19	LATITUDE, SM (DEG)	-6
20	LOCAL TIME, SM (HR)	-7
21	RADIUS, GSM (EMR)	-7
22	LATITUDE, GSM (DEG)	-6
23	LOCAL TIME, GSM (HR)	-7
24	B, (nT)	-4
25	BX, ECI (nT)	-4
26	BY, ECI (nT)	-4
27	BZ, ECI (nT)	-4
28	MAGNETIC LOCAL TIME (HR)	-7
29	SOLAR ZENITH ANGLE (DEG)	-6
30	INVARIANT LATITUDE (DEG)	-6
31	B100N LATITUDE (DEG)	-6
32	B100N LONGITUDE (DEG)	-6
33	B100S LATITUDE (DEG)	-6
34	B100S LONGITUDE (DEG)	-6
35	L-SHELL (EMR)	-7
36	BMIN (nT)	-4
37	BMIN LATITUDE (DEG)	-6
38	BMIN LONGITUDE (DEG)	-6
39	BMIN ALT (KM)	-4
40	BCONJ LATITUDE (DEG)	-6
41	BCONJ LONGITUDE (DEG)	-6
42	BCONJ ALT (KM)	-4
43	X SUN POSITION-ECI (KM)	0
44	Y SUN POSITION-ECI (KM)	0
45	Z SUN POSITION-ECI (KM)	0
46	X MOON POSITION- ECI (KM)	0
47	Y MOON POSITION-ECI (KM)	0
48	Z MOON POSITION-ECI (KM)	0
49	RIGHT ASCENSION OF GREENWICH	-6
50	B100N MAG FIELD (nT)	-4
51	B100S MAGNETIC FIELD (nT)	-4
52	Mx DIPOLE MOMENT-ECI (nT)	-4
53	My DIPOLE MOMENT-ECI (nT)	-4
54	Mz DIPOLE MOMENT-ECI (nT)	-4

55	Dx DIPOLE OFFSET-ECI (KM)	-4
56	Dy DIPOLE OFFSET-ECI (KM)	-4
57	Dz DIPOLE OFFSET-ECI (KM)	-4
58-60	VACANT	

- (A) MAG - MAGNETIC COORDINATES; THE Z AXIS IS PARALLEL TO THE DIPOLE, AND THE SOUTH GEOGRAPHIC POLE IS IN THE +X,Z PLANE.
- (B) SM - SOLAR MAGNETIC COORDINATES; THE Z AXIS IS PARALLEL TO THE DIPOLE, AND THE SUN IS IN THE +X,Z PLANE.
- (C) GSM - GEOCENTRIC SOLAR MAGNETOSPHERIC COORDINATES; THE X AXIS IS PARALLEL TO THE EARTH - SUN LINE, AND THE EARTH'S DIPOLE IS IN THE X,+Z PLANE.
- (D) EMR = 6371.2 KM
- (E) THE EQUATORIAL RADIUS IS DEFINED AS 6378.135 KM, AND THE FLATTENING IS 298.26.

## 21.0 ATTITUDE DETERMINATION INFORMATION

The attitude determination fit coefficients are generated as part of the Agency Tape generation process. The routines which produce the coefficients use spacecraft sun sensor, horizon sensor and magnetometer data as their prime inputs. The attitude coefficient file used as part of the THDB is identical in structure to the attitude coefficient file store on the Agency Tapes.

### 21.1 ATTITUDE COEFFICIENT FILE FORMAT

This file contains the output of the attitude determination program. Data records are in ASCII. The data consists of a series of time tagged coefficients from fits of attitude motion. These parameters are used with software (program AGMOD) provided to the agencies to calculate their sensor LOS as a function of time. The file structure consists of a header information followed by the fit coefficient data.

#### 21.1.1 HEADER INFORMATION

RECORD NUMBER	DESCRIPTION	WORD TYPE
1	FILE NAME	ALPHA
2	VEHICLE ID	ALPHA
3	GTO (LAS) PERIOD NUMBER	ALPHA
4	YEAR	INTEGER
5	DAY OF YEAR	INTEGER
6	UT AT START OF DATA (MS)	INTEGER

7	UT AT END OF DATA (MS)	INTEGER
8	NUMBER OF FIT SPANS	INTEGER

### 21.1.2 FIT COEFFICIENT RECORDS

RECORD NUMBER	DESCRIPTION	WORD TYPE
1	INDEX (STATE VECTOR) NUMBER	INTEGER
2	SEGMENT START TIME (SEC)	FLOATING
3	SEGMENT END TIME (SEC)	FLOATING
4	TIME CONVERSION SCALE FACTOR	FLOATING
5	TIME CONVERSION OFFSET FACTOR	FLOATING
6	CONDITION FLAG NUMBER	INTEGER
7	ORDER OF RA FIT COEF (N1)	INTEGER
8	SPIN AXIS RA FIT COEFFICIENT 1	FLOATING
9	SPIN AXIS RA FIT COEFFICIENT 2	FLOATING
.	.	.
.	.	.
.	SPIN AXIS RA FIT COEFFICIENT N1	FLOATING
.	ORDER OF DEC. FIT COEFFICIENT (N2)	INTEGER
.	SPIN AXIS DEC. COEF. 1	FLOATING
.	SPIN AXIS DEC. COEF. 2	FLOATING
.	.	.
.	.	.
.	SPIN AXIS DEC. COEF. N2	FLOATING
.	ORDER OF SPIN RATE FIT COEF. (N3)	INTEGER
.	SPIN RATE COEF. 1	FLOATING
.	SPIN RATE COEF. 2	FLOATING
.	.	.
.	.	.
.	SPIN RATE COEF. N3	FLOATING
.	SPIN PHASE AT START OF SEGMENT	FLOATING